HOUSE ORGAN OF O'ALLOYS GENERAL ALLOYS COMPANY

ALLOY PROGRESS

EDITED BY H. H. Harris PRESIDENT

Bright Spot in Metal Progress

ENTIRELY ABOUT HEAT & CORROSION RESISTANT ALLOY CASTINGS

COMMENT

WHO sugared the first "Pill" is lost in the dawn of history, but our use of photos and extraneous "copy" is obviously for one reason,—to intrigue and compensate the Reader. If you think our advertising claims "Extravagant," visit us at the Steel Show, and we'll show you castings, records, photos, testimonials, to back them up.

YOU can *go* places and *see* things when you have wings, combining elevation, elation and transportation. Labor Day I took in the National Air Races at Cleveland, then hopped over to circle the course at the "Gold Cup" International Speed Boat Race at Detroit. The snap-shots I took from the air (see page 7) will appear in several leading publications. Thirty-two of my pictures were published last month, ranging from the *Chicago Tribune* to the cover of *Financial World*, and I'm getting bored taking them.

COUNT Otto Hagenburg; German, Champion Aerobatic Flyer of Europe, flew upside-down with head clearing ground by 6"—5"—4"—3"—2"—1", *then* 0". His temples dragging, Count and plane were rolled into a ball,—ship completely scrap. He staggered, trailing blood, to the ambulance. Two days later,—how's this for GUTS,—he borrowed the sporting Captain Papana's (of Roumania) "ringmeister" plane, thrilled the crowd with whip-stalls, inverted flying and outside loops,—this while they were looking for him at the hospital. The Women Pilots, you can tell them by their sunburned knees, were a problem. The girls were afraid to race together,—just sisterly distrust of wild piloting, so they let them race one at a time. One was beefing, "The cost of flying lessons is bad enough, but on top of that one must put out for fancy lingerie,—just in case they bring you home in a basket."

IF you have any hot conveying problems, see us at the Steel Show.

ALLOY PROGRESS is reprinted and mailed to Executives of companies employing A.S.M. members, and to selected non-members. The September reprint carried a special full page message from "Bill" Eisenman urging attendance at the Steel Show. 11,000 additional pieces of G.A. direct mail, urging show attendance, are going out in October.

BY focusing attention of Industry on Metallurgy and Technology, A.S.M. has made a far bigger field for the talents, and increased the earnings of, every technician, steel treater, and salesman in the Metals Industries.

"Bill" Eisenman's efforts have put extra $ in thousands of pay envelopes. Nowhere can $10 buy what it buys in A.S.M. Membership.

I have spent my business life with the "Steel Treaters" and A.S.M.; enjoy these associations as friendships ripen through the years, and each "Steel Show" is a milestone for us all. On the pages that follow you will see a range of alloy experience and a variety of foundry practice that cannot be equalled by the combined experience of an industry. Study this double page spread on foundry practice, *it's a credit to American craftsmen.*

H. H. H.

FIREWORKS
We always try to get all the angles possible. Whether it's climbing under a furnace, or up on top of a fireworks display, you can depend on G.A. to do the unusual thing, and bring back results.

"J" BOATS
With The King building an "L" Boat, and everybody admitting that "Ranger" has out-jayed the "J" Boats for all time, this view, through the struts of the five "J" off Marblehead (including Ranger and two Endeavours), probably shows the last big "J" race.

HINGED-TRAYS
If you have any doubt that hinged-trays will save money in your furnaces, drop into G.A. Booth at the Steel Show.

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

GA X-ITE GA O'ALLOYS GA X-ITE GA O'ALLOYS

John Heckman, District Sales Mgr., Chicago

A. L. Grinnell, Detroit Sales Manager

C. R. "Slats" Slebsby, Milwaukee

"Bill" Bender, Pittsburgh

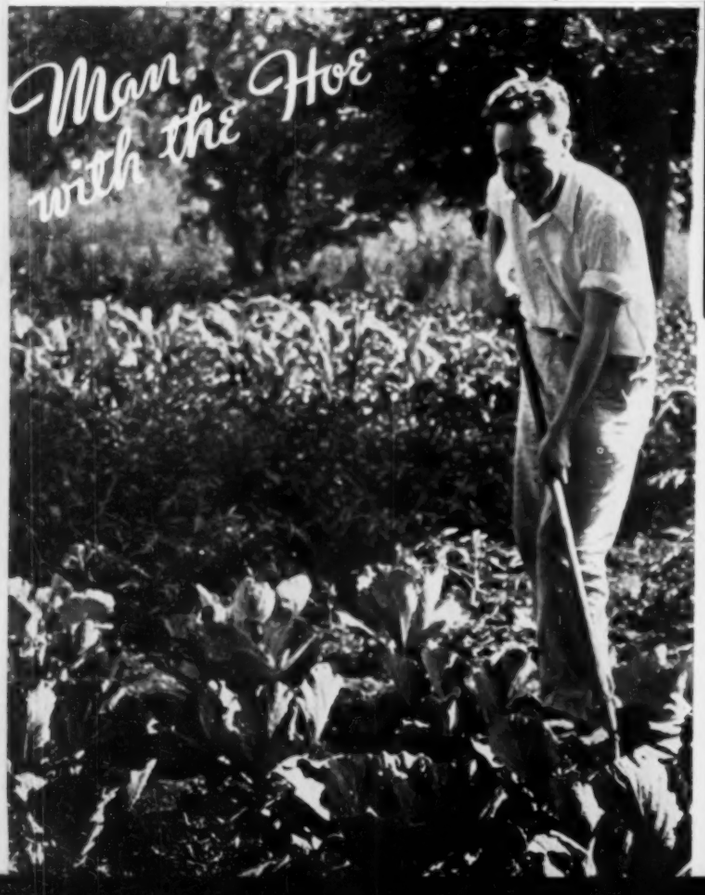
Roy Lynd, Buffalo

Walter Hazelton
Field Engineer, Detroit

Bill Fitzpatrick
Philadelphia

Ken Brintling
Field Metallurgist

"Hal" Chase, District Sales Mgr., Ohio. Nobody would believe me when I told about Hal's vegetables winning prizes—so here's the photo



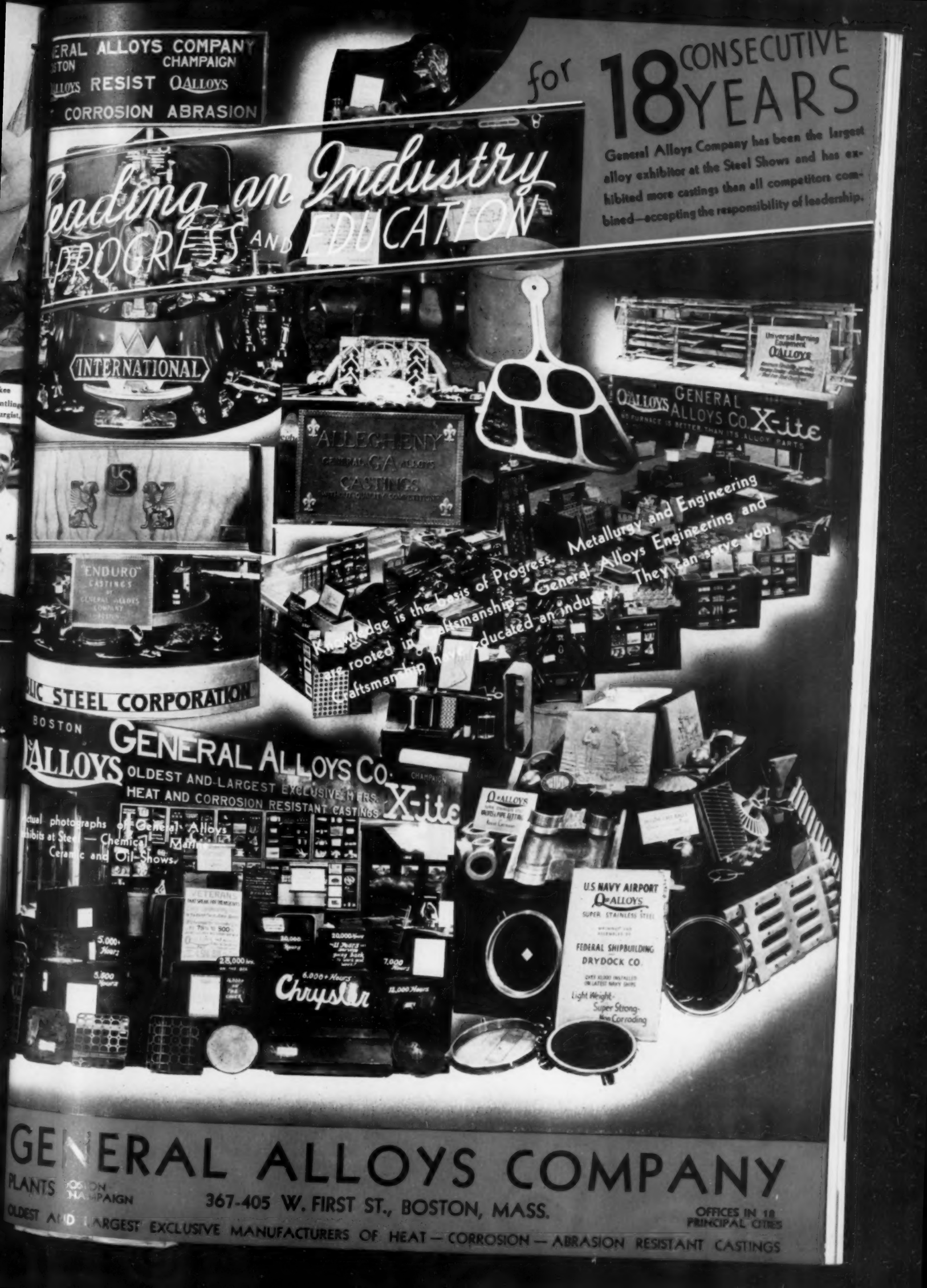
GA *Men* Make General Alloys.

No organization is stronger than the men who serve its customers. You can find all of these men when you want them and when you find them together at the steel show you will meet competent, substantial, experienced alloy men, the only national engineering organization in this industry.

"Whitey" Valentine, Dayton (AECVE)

J. J. "Jerry" Donovan

"ART" PAINTER — N. Y. SALESMGR.


ERAL ALLOYS COMPANY
STON
CHAMPAIGN
ALLOYS RESIST QALLOYS
CORROSION ABRASION
for 18 CONSECUTIVE YEARS
General Alloys Company has been the largest alloy exhibitor at the Steel Shows and has exhibited more castings than all competitors combined—accepting the responsibility of leadership.
Leading an Industry
PROGRESS AND EDUCATION
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ALLEGHENY
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CASTINGS
QALLOYS GENERAL ALLOYS Co. X-ite
"ENDURO"
CASTINGS
Knowledge is the basis of Progress. Metallurgy and Engineering are rooted in craftsmanship. General Alloys Engineering and craftsmanship have educated an indu
They can serve you.
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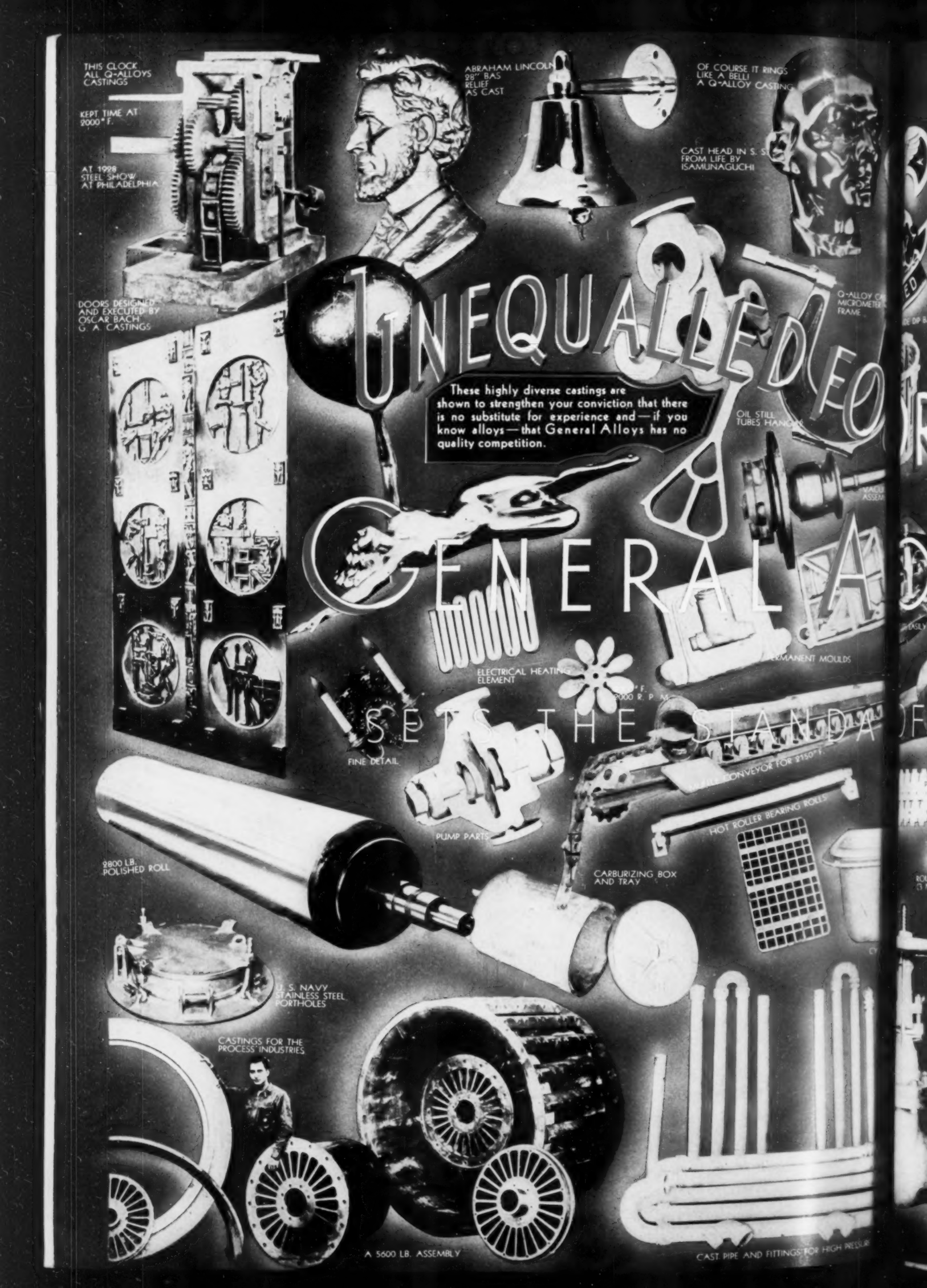
OFFICES IN 18 PRINCIPAL CITIES
OLDEST AND LARGEST EXCLUSIVE MANUFACTURERS OF HEAT — CORROSION — ABRASION RESISTANT CASTINGS


THIS CLOCK ALL Q-ALLOYS CASTINGS
KEPT TIME AT 2000° F.
AT 1928 STEEL SHOW AT PHILADELPHIA
ABRAHAM LINCOLN 28" BAS RELIEF AS CAST
OF COURSE IT RINGS LIKE A BELL! A Q-ALLOY CASTING
CAST HEAD IN S. S. FROM LIFE BY ISAMUNAGUCHI
UNEQUALLED
These highly diverse castings are shown to strengthen your conviction that there is no substitute for experience and — if you know alloys — that General Alloys has no quality competition.
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Q-ALLOY
MICROMETER FRAME
OIL STILL TUBES HANDLE
GENERAL A
ELECTRICAL HEATING ELEMENT
PERMANENT MOULDS
SETS THE STANDA
FINE DETAIL
PUMP PARTS
HOT ROLLER BEARING ROLLS
CARBURIZING BOX AND TRAY
2800 LB. POLISHED ROLL
U. S. NAVY STAINLESS STEEL PORTHOLES
CASTINGS FOR THE PROCESS INDUSTRIES
A 5600 LB. ASSEMBLY
CAST PIPE AND FITTINGS FOR HIGH PRESSUR

UPJOHN BUILDING
STAINLESS LETTERS
AND TRIM
ALBERT KAHN
ARCHITECT
PROPELLER FOR
A WORLD'S CHAMPION
G. A. STAINLESS
LITTLE ONES TOO!
U P J O H N
RY PRACTICE
1933
PLAQUES ON THE
ENTRANCE GATES
CHICAGO FAIR
CHRYSLER BUILDING
10" HIGH IN
Q-ALLOY
"TRICK" CASTINGS
ARE OUR MEAT
CAST TUBE 14 FT. LONG
A CENTURY
OF PROGRESS
CHICAGO
DYS COMPANY
"KLOIZENAY" FUSED GLASS
ON LIVING STEEL
CHEMICAL PIPING
CAST CLOCK CASE
A FURNACE CAST IN ONE
600 LB. PIECE
F ALL FOUNDRY ART
CEMENT MILL PARTS
CONVEYOR FURNACE
SPROCKET
A COMPLETE LINE OF
LINK-BELT TYPE
CHAIN
PATENTED
ROLLER RAILS
(3 MILES IN SERVICE)
HINGED FURNACE TRAY (PATENTED)
CAST CORNER SHEET
CARBURIZING BOX
PAT'D.
RACKS FOR
DECORATING KILN
30,000 patterns and *more* comprise the foundry experience of the oldest and largest exclusive manufacturer of heat and corrosion resistant castings.
The casting of complex alloys is still more an art than a science and General Alloys' New England craftsmen excel in that art as General Alloys' engineers and metallurgists excel in alloy technology.
X-HE RETORT CASTINGS FOR
ATMOSPHERE AND CARBURIZING
FURNACES
YOU NAME THIS ONE

It is distinctly unique that the highest quality manufacturer should have largest installations, that the highest quality, and necessarily h priced alloys, should enjoy the greatest sale. The scope of General Alloys Installations, the vol Q-Alloy sales is Industry's reward to us for p and Education, unequalled foundry and engineering service by con alloy men. We strive to industry's confid and yours.

The General Alloys Company Merits Your Business on the Basis of Unequalled Experience — Quality — Servic

Q-ALLOYS

"STAND UP UNDER FIRE"

Backed by a National Engineering Service

THESE photographs should give you a fair idea of the diversified experience of General Alloys Company, of the facilities and engineering setup making such work possible.

COMPLEX alloys are a relatively new development—there is still no literature on the art of manufacture—and because of the tremendous variety of analyses, properties, forms and applications, the business is still more an art than a science.

WHILE our operations are subject to every known scientific control and we are in the foreground of metallurgical progress we can find no substitute for the fine hand molding craftsmanship in our shops and no substitute for years of alloy engineering experience for our field force.

Q-ALLOYS have been made in more than 30,000 different forms, each with its specialized problems of application and manufacture. This is essentially a jobbing business, very little of it on a production basis. Casting complex alloys is not amenable to the volume inspections and control of a sheet mill—nor can many machines and steel foundry labor be utilized. Trained men make quality possible.

GENERAL Alloys' business is 100% manufacture of complex alloys—nowhere is there such a fund of experience as is placed at your disposal when you consult this company.

WHETHER your requirements are containers—*in which we have the largest and lowest cost per heat hour installations*—or complex corrosion resisting alloys—*here we have a unique record*—you can certainly find no one fitted to serve you so well.

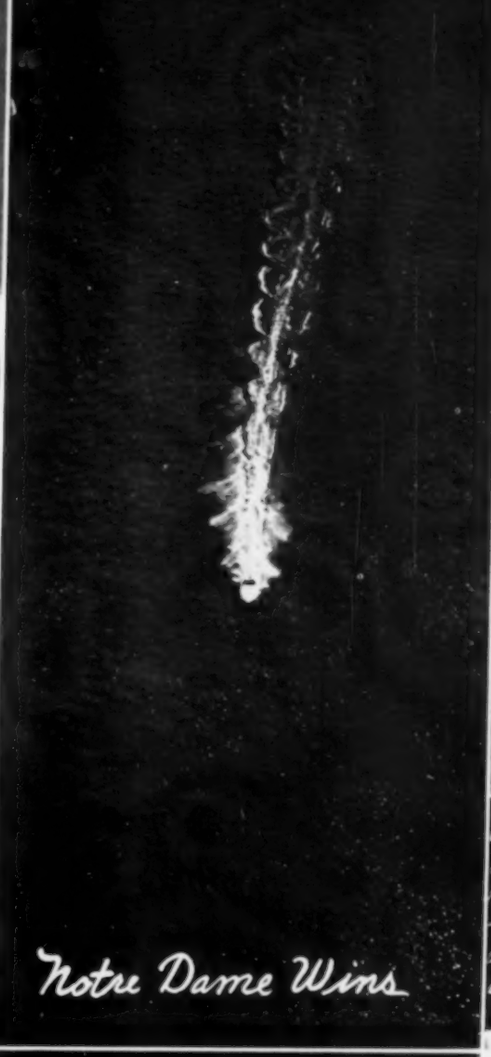
NO FURNACE IS BETTER THAN ITS ALLOY PART

■ SPECIFY GENERAL ALLOYS CAST PARTS AND GET THE BEST

National Air Races —

go up on top and look at the Army—

t Otto Hagenburg of Germany



Notre Dame Wins

Cleveland
LABOR DAY

—then dive down and shoot up at

Try to do this

Cliff Henderson
Air Race Maestro

Just three hours flying on a Holiday Afternoon —and getting what we go after —H.H.H.

Flown and Photographed
by
H. H. HARRIS
PRESIDENT
GENERAL ALLOYS
COMPANY
BOSTON

Rudy Kling new sp
King wins Thompson
Trophy

Gold Cup Races —

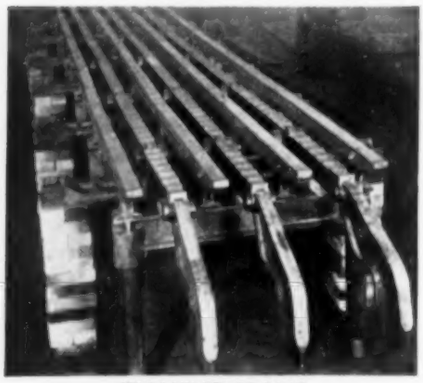
ere Goes the Gold Cup Race—and

Detroit
LABOR DAY

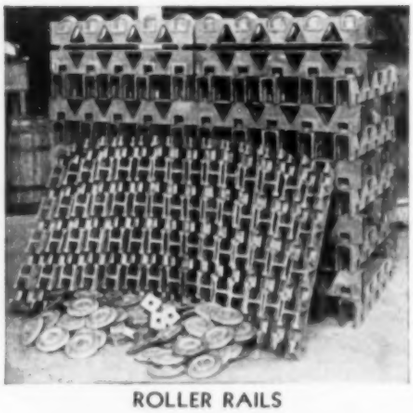
Notre Dame Crosses the line—Winne

Leading Furnace Manufacturers Use CALITE

Chromium-Nickel Alloy Castings



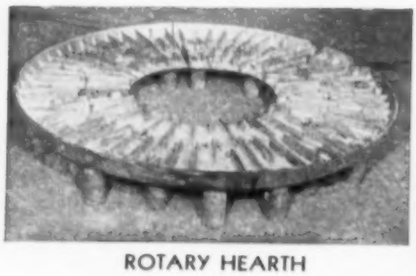
WALKING BEAMS



ROLLER RAILS

CONVEYOR ROLLERS
(Centrifugally Cast)

POTS



ROTARY HEARTH

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at these photos of

CALITE

Furnace Parts for

5

Prominent Furnace Builders

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WHY?

Lowest Cost per Heat Hour

due to . . .

- Highest *Creep Strength*
  (Load Carrying Under Heat)
- *Permanent Ductility*
- Full *Engineering Data*
- Superior *Foundry Technique*
- *Centrifugal Casting*
- Widest *Selection* of Hi-Temp. Metals
- 14 YEARS EXPERIENCE

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World's Largest Manufacturer of High Temperature Metals

420 HILL AVENUE (Wilkinsburg Station) PITTSBURGH, PA.

The Status of Welding in 1937

By Leon C. Bibber
Welding Engineer
and Elmer Gammeter
Metallurgical Division
Carnegie-Illinois Steel Corp.

(Photographs selected by the Editor)

Giant Salt Maker, an Evaporator 12 Ft. Diameter by 50 Ft. Long; Shell of Steel Plate, Arc-Welded by Wellman Engineering Co. (Courtesy of Lincoln Electric Co.)

1937 HAS SEEN the greatest increase in the use of welding since it left the blacksmith's forge, a fact realized by few people not directly connected with the welding industry. The extent to which welding enters into everyday affairs is seldom appreciated even by engineers who are working with metals. Welding has revolutionized the manufacture of practically all metal articles; from the railway car and the automobile body in which we ride to the electric lamp which lights our homes; from the child's toy to massive rolling mill machinery; from small cooking utensils to the huge stills used in the chemical industry. Welding is not limited to any one metal or group of metals — it has, as a result of persistent and painstaking research, conquered practically all the metals now in commercial use.

By virtue of the fact that joints of 100% efficiency can be secured, designs which were impossible with the older jointing methods are now everyday affairs; because structures can be made with greater resistance to fatigue and vibration by welding than by any other means, the present day automobile and other moving structures are possible; because of the great savings in weight that can be made by welding, giant mobile machines such as earth graders, trenchers, excavating machinery and concrete mixers are now doing work unheard of some few years ago.

Welding has entered all fields of engineering. The mechanical engineer could not have the light, strong, rigid machinery nor the high pressure boilers and vessels which are now at his command if it were not for welding; the chemical engineer could not have the corrosion resisting vessels he now has; the marine engineer could not have the added cargo capacity; the automotive engineer could not make the vehicles which now crowd our roads; the rail-

way mechanical engineer could not have the light, attractive rolling stock which is so rapidly bringing the railroads back into the forefront; the electrical engineer could not have the efficient electrodynamic machinery that has recently been developed.

One of the most interesting phases of the rapid rise of welding has been its close connection with high tensile alloys. If a designer is interested in saving weight, he cannot afford to overlook the advantages of the present day high tensile steels and the strong, light alloys, and if reduction in weight is of sufficient interest to require their use, it is inconsistent to ignore the great weight-saving possibilities of welding. High tensile alloys and welding go hand in hand in reducing useless weight; some of them have presented difficult welding problems but these are being overcome.

Welding has, in the past, been classified in two groups: *(a)* fusion welding processes and *(b)* resistance welding processes. This grouping is not satisfactory, because practically all welding involves fusion whether that fusion result from the heat of an electric arc, a gas torch, or electrical resistance. In this review, therefore, welding processes will be considered in another classification: *(a)* Non-pressure processes and *(b)* pressure processes. This grouping, likewise, is not entirely satisfactory as there is considerable overlapping, but it is useful in connection with any general discussion of the subject.

Non-Pressure Welding Processes

Bare Metal-Arc Welding — Welds made by the metal-arc process, using as an electrode merely a bare wire, still have considerable application in non-hazardous work. Its weld metal has relatively little ductility and has tensile strength not as great as that of ordinary mild steel. Nitrogen to the extent of possibly 0.12 to 0.15% is absorbed from the atmosphere and has a very harmful effect upon ductility at the joint. However, in spite of these limitations there remain many places where bare electrode welding is good enough for the purpose.

Shielded Metal-Arc Welding uses a covered or coated electrode, designed to protect the arc and the molten deposited metal from contamination by the atmospheric gases. This has been accomplished so effectively that the nitrogen in the deposit can readily be held to less than 0.02%, and ductility of good shielded-arc weld metal may range from 20% to 35% in 2 in. and tensile strength be considerably greater than that of ordinary mild steel. Shielded-arc electrodes can be used in all positions and can be used for the welding of high tensile steels.

Shielded metal-arc welding is the process generally referred to when the word "welding" is used without qualification. It is probable that the consumption of electrodes during 1937 will exceed 125,000,000 lb., of which the shielded electrodes form, by far, the larger part. High tensile electrodes, particularly of the carbon-molybdenum group, have been brought to a high state of perfection recently and are widely used in equipment for high temperature service.

Shielded Carbon-Arc — In this process the heat is obtained from an arc between the base metal and a carbon or graphite electrode. Direct current must be used with "straight" polarity — that is, the current must be flowing from the work to the electrode so that the base metal is not carburized. The shielding of the carbon-arc can be done by burning a foreign substance such as impregnated "rope" alongside the arc, or by partially smothering the arc in a heavy flux, or by a combination of such methods. Filler metal may or may not be used. The carbon-arc is capable of relatively great output and admirably adapted to multiple production work; properties of shielded carbon-arc metal are comparable to those of shielded metal-arc weld metal.

Conductive Melt Welding — This term is advanced, provisionally, to describe a relatively new automatic process in which a bare electrode is used in coil form and the welding takes place underneath a heavy flux called the "melt." No arc is visible and it is claimed that no arc is formed, that the heat is generated as a result of electrical resistance offered by the flux (which has become liquefied); the base metal is melted as a result of its proximity to this strongly heated flux. Since the current is put into a bare wire and since the process is necessarily automatic, currents of several thousand amperes can be readily used. Great penetration is possible. Pieces several inches thick can be welded in one pass by this method.

Thin-Walled, Alloy Steel Tubing and Oxy-Acetylene Welding Make an Ideal Combination for Engine Mounts and Landing Gear for Aircraft. Photo by Hine

The resulting weld metal has a very coarse columnar structure but nevertheless has properties comparable with shielded metal-arc weld metal of high grade. The process is now in use in a number of multiple production plants; perhaps the most striking example is the welding of the midship section of large tankers in a shipyard on the Eastern coast.

Gas Welding — Gas welding is the generic term applied to all forms of welding wherein the heat is obtained from the combustion of gases. Two gases are used, one the fuel gas and the other, the supporter of combustion. Many kinds of fuel gas can be used depending on the work to be done — acetylene, city illuminating gas, natural gas, propane, hydrogen — while but two supporters of combustion are used, namely, oxygen and air. Acetylene and oxygen are the usual combination, because oxy-acetylene welding can be applied to practically all metals and is particularly useful in the non-ferrous field. It is also used in automatic installations where multiple-nozzle torches permit high rates of production. The weld metal can be alloyed in various ways to obtain almost any desired combination of properties.

Flame Hardening — This process, while not welding, is so closely allied thereto that it should be considered in connection with gas welding. Flame hardening has made great progress recently; a comprehensive account was published last month in METAL PROGRESS. In this process gear teeth and other parts which are to be surface hardened, are heated locally to the necessary temperature by means of the torch; heating is followed closely by cooling with water to bring about the desired quench. By means of this process many difficult problems in heat treating are avoided.

Thermit Welding is a most interesting form of welding in which the heat is obtained from the chemical reaction between aluminum and iron oxide. A specially prepared mixture of powders is used and upon being ignited the reaction spreads through the mass, placed in a crucible, and such intense heat is generated that the molten steel so reduced attains a temperature of probably more than 4000° F. This temperature is sufficient so that the superheated metal, entering a mold prepared about the parts to be joined, heats the cooler base metal to the melting temperature; base metal and filler metal subsequently solidify together and form a true weld.

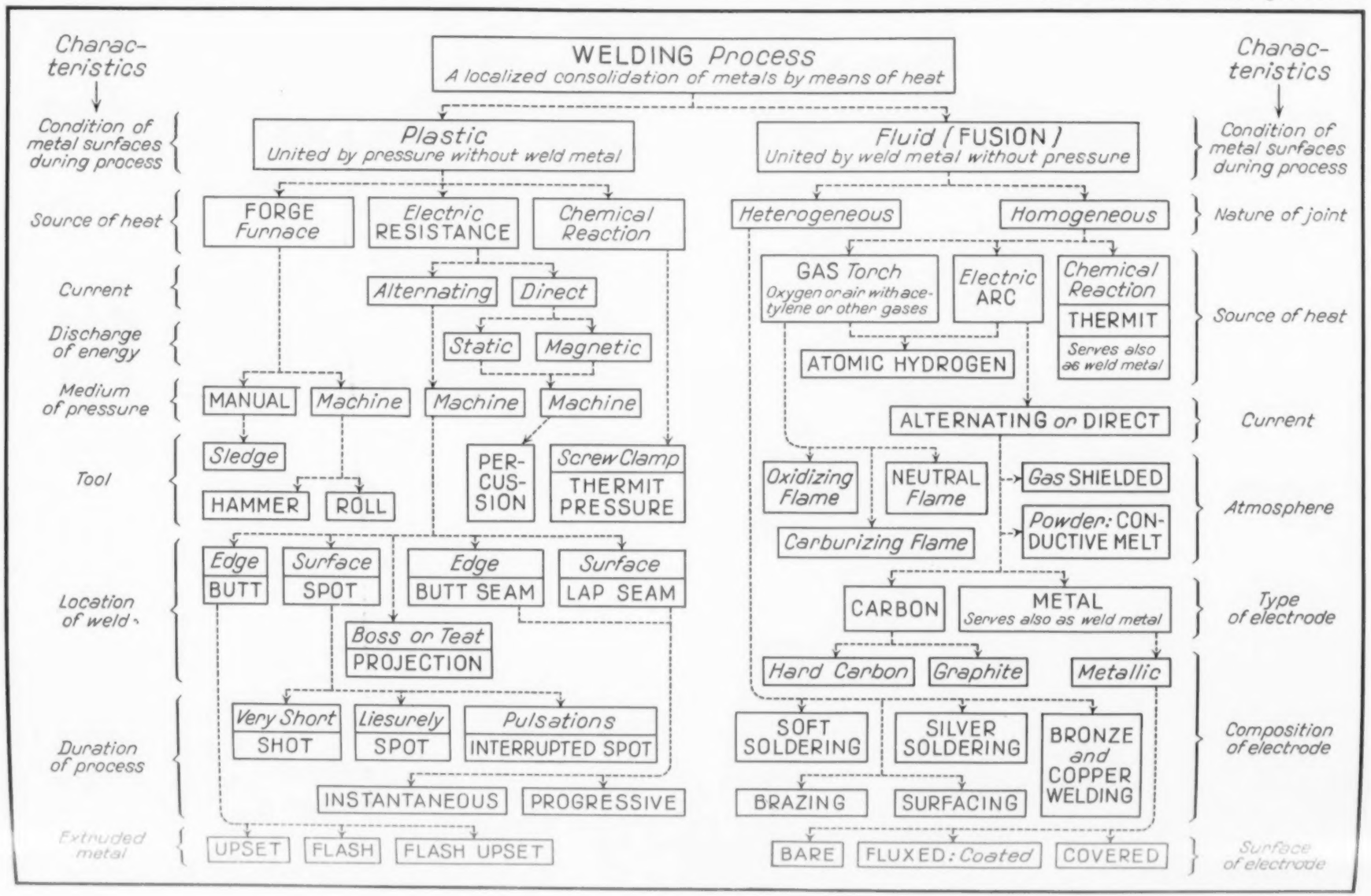
Thermit welding is especially adaptable to the welding of heavy sections, cast or forged, such as large mill shafting, engine frames or stern posts. A wide range of properties can be obtained through suitable alloying. The thermit process is receiving constantly greater application in the welding of rails. The rail joint in use today is a combined non-pressure and pressure weld, the web and lower flange of the rail being welded by non-pressure process and the head of the rail being welded by the application of pressure.

Hard Surfacing — that is, the coating of a softer base metal with a harder deposit — is continuing to increase in importance not only in repair work but in the production of new products. *(Continued three pages further on)*

Chart Classifying the Principal Welding Processes

Adapted from F.T. Llewellyn

CAPITALS indicate terms in general use

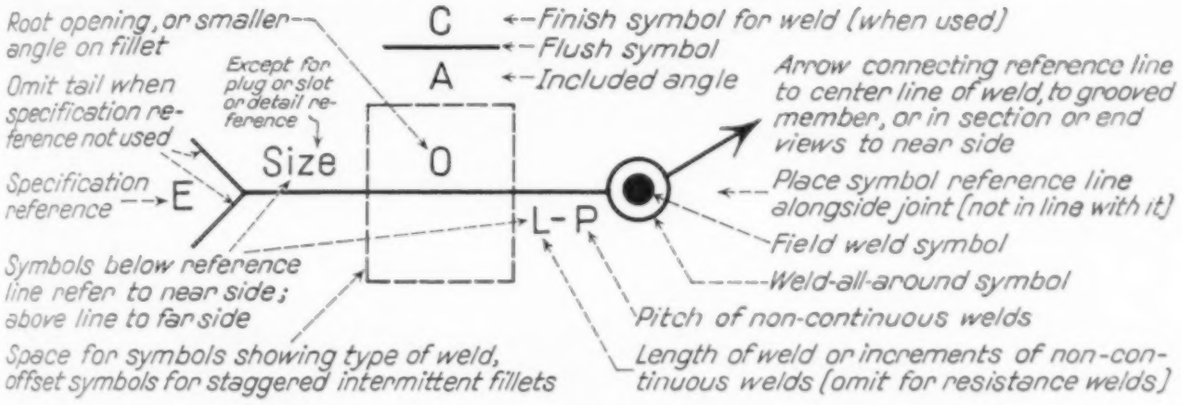


Welding Symbols

Adopted as Standard by American Welding Society, 1937

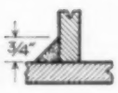
For Fusion Welding								For Both			For Resistance Welding			
Type of Weld											Type of Weld			
Bead	Fillet	Groove					Plug & Slot	Field Weld	Weld All Around	Flush	Spot	Projection	Seam	Butt
		Square	Vee	Bevel	U	J								
⌒	◺	ı	V	V	Y	Y	▽	•	○	—	✳	✕	XXX	ı

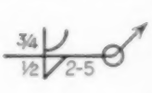
Standard Location of Information on Welding Symbols


C
A
Size
E
0
L-P
Root opening, or smaller angle on fillet
Except for plug or slot or detail reference
Omit tail when specification reference not used
Specification reference
Symbols below reference line refer to near side; above line to far side
Space for symbols showing type of weld, offset symbols for staggered intermittent fillets
Finish symbol for weld (when used)
Flush symbol
Included angle
Arrow connecting reference line to center line of weld, to grooved member, or in section or end views to near side
Place symbol reference line alongside joint (not in line with it)
Field weld symbol
Weld-all-around symbol
Pitch of non-continuous welds
Length of weld or increments of non-continuous welds (omit for resistance welds)

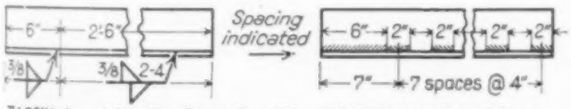
Significance of Typical Combinations

Indicates continuous ¾" fillet weld on near side, made under shop's own specification A,



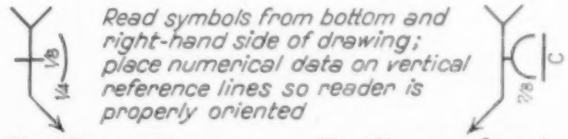


Significance: Weld all around (encircling member as far as possible). Near side: ½" fillet, 2" long, 5" on centers. Far side: plate has ¾" J groove (shop's standard), continuous weld



⅜" fillet weld both sides for 6". Welds on both sides are same size unless noted

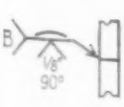
⅜" fillet welds 2" long, 4" on centers, opposite sides staggered


⅛
¼
Read symbols from bottom and right-hand side of drawing; place numerical data on vertical reference lines so reader is properly oriented
⅞
C

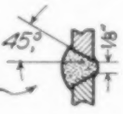
Significance: Square edges on plates clearing ⅛", welded from near side, ¼" penetration required

Significance: Closely abutting plates with U groove ⅞" deep, near side chipped smooth

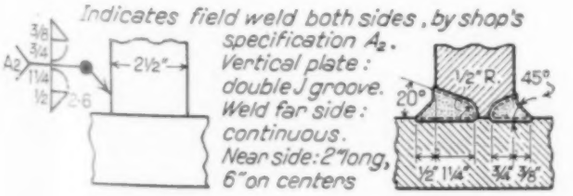
When one member only is to be grooved arrows point to that member, thus:



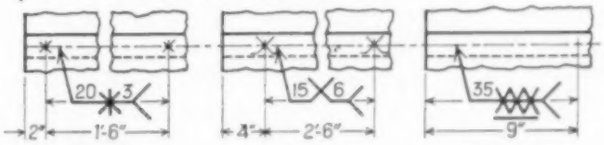
Indicates plates bevelled at 45°, root opening ⅛" on assembly, bead deposited on root side



Symbols govern to break in continuity of structure or to extent of hatching or dimension lines. Strength of resistance welds in hundreds of pounds noted instead of size:



Indicates field weld both sides, by shop's specification A2. Vertical plate: double J groove. Weld far side: continuous. Near side: 2" long, 6" on centers



2000-lb. spot welds, @ 3" centers

1500-lb. projection welds @ 6" centers

3500-lb. seam weld, 9" long, flush near side

For other combinations see "Welding Journal", June 1937

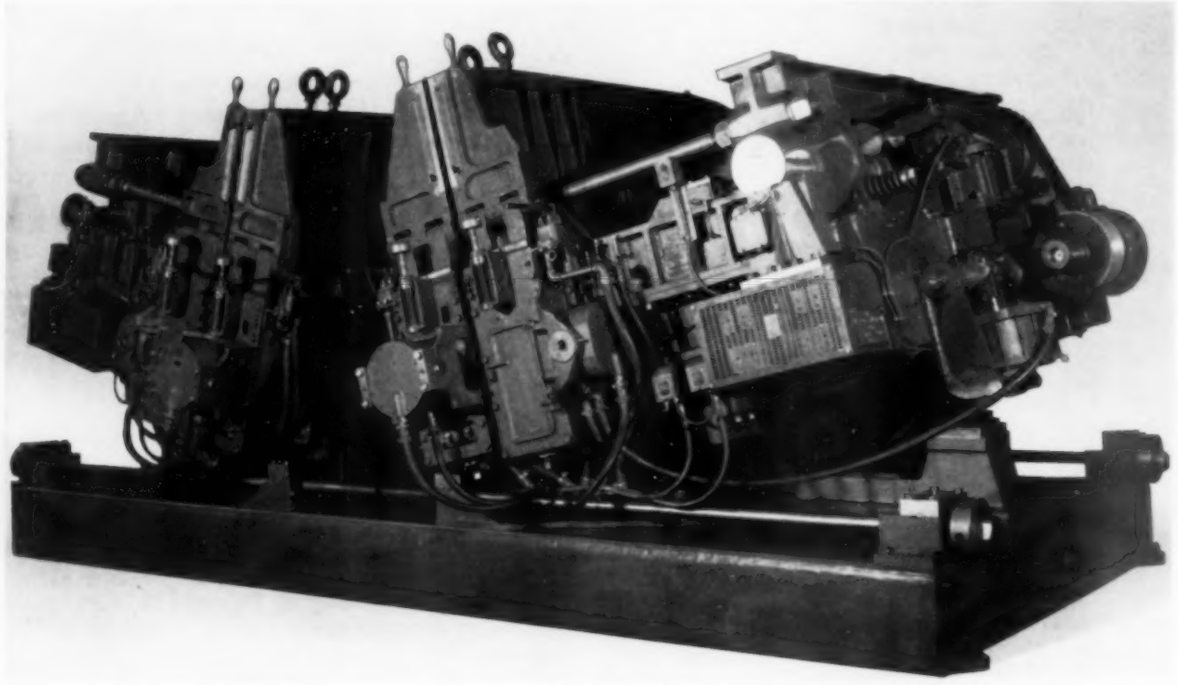
Welding in 1937

An interesting example of this is the coating of certain areas of water-turbine runners to prevent cavitation, and the under surfaces of gas engine valves to prevent damage by hot exhaust gases. Almost any degree of hardness can be obtained and many different compositions can be deposited. Hard surfacing may be done by the gas or metal-arc processes. The life of earth-working machinery, drilling tools, forming tools, cutting dies, is increased often many hundred per cent by the use of hard surfacing alloys better able to withstand shock and abrasion than the alloys forming the body of the part.

Brazing may be defined as a non-pressure welding process in which a bond is obtained between a material of a lower melting point and one of a higher melting point. There is considerable evidence that an alloy is formed, at the bond, with a melting point less than that of the parts being joined. Brazing, of course, originally meant joining by the use of brass, but the term is now applied to joining with pure copper, with silver alloys and many other alloys. Brazing may be done by the gas process, by the electric resistance process or by any external source of heat. The operation may be conducted in air or in special atmospheres, such as hydrogen. Very good and strong joints may be obtained when the correct choice of brazing material, in reference to base material, is made.

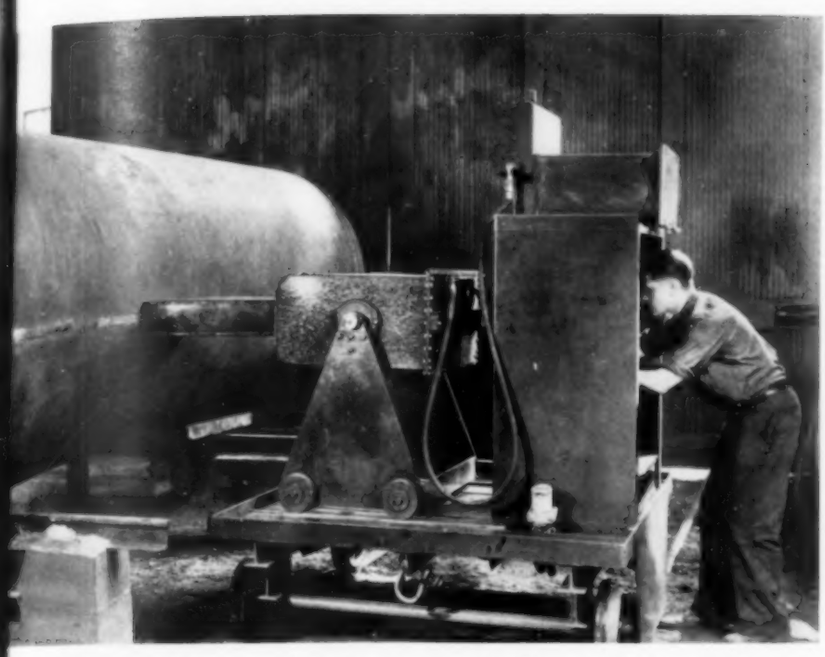
Pressure Processes

Pressure processes include the old fire weld or blacksmith's forge weld as well as the very modern forms of resistance welding. The latter have not been given the prominence they deserve. There are more welds made by pressure methods than by all the other processes combined. Most multiple production welding is done by these means. They are being increasingly used on aluminum alloys and other non-ferrous metals (see the article by D. I. Bohn in July METAL PROGRESS).



Flash Welders Grow to Enormous Dimensions When Their Dies and Transformers Are Large Enough to Weld Sheet Metal Panels Into Complete Automobile Bodies. Photo courtesy Taylor-Winfield Corp.

The equipment provided for resistance welding removes the so-called human element from the job. The machines can be set to do the work properly and will, with reasonable



X-Ray Inspection — a Code Requirement for Class I Welding — Has Eliminated Guesswork as to the Soundness of Important Welded Joints. Photo at plant of Farrar & Trefts

attention, retain this setting so that the welds made are practically identical and can be made as rapidly as the machine is operated. Great speeds are possible; spot welds have been made as rapidly as 250 per min. It is not surprising that since uniformity and high speed are available, resistance welding should be much used in multiple production work.

There is need today for criteria for judging the merit of the welds. In the case of metal-arc welding, a good weld is one that has properties comparable to the base metal. In the case of resistance welds, just what constitutes a good weld is not so well established.

Spot Welding — A spot weld results from the melting due to the resistance of the contact surfaces between two or more parts to the passage of an electric current. In a two-ply spot weld there are three contact surfaces, namely, the contact surface between one sheet and one electrode, the surface between the other sheet and the other electrode, and the faying surface between the two sheets. The resistance at the faying surface is the greater; hence heating starts at this point. When fluidity has been obtained, the weld is consummated by mechanical pressure from the electrodes.

There are three fundamental variables, current, time, and pressure, and the best combination of these three is generally only secured by experiment. The time involved is often very brief. Welds can be made in as short a time as ½ cycle; that is, 1/120 of a sec.; on the other hand, a weld may require as much as one full second. It can be seen that if time must be measured in fractions of seconds, the human mind and body is not capable of reacting with any such rapidity; to secure uniformity of results, timing devices are necessary. These may be simple contactor timers actuated magnetically, mechanically, or by any other convenient means, and mechanical timers are accurate enough for many commercial uses. On the other hand, when the austenitic stainless steels are to be used, or very thin gage material, more accurate timing is required and some very fine timers utilizing vacuum tubes are now on the market. These thermionic timers are capable of cutting on the current accurately and consistently at the zero point in the sine wave (or at other point if desired) and are capable of controlling welding times up to about 30 cycles in length.

It will be seen that the rapidity of spot welding implies very rapid cooling. The small globule of molten metal surrounded by a cold mass of base metal is subjected to drastic quenching. For this reason it is desirable to minimize the hardening elements in ferritic steels designed for spot welding. On the other hand, the austenitic stainless steels, by virtue of the fact that they do not harden upon quenching, are ideal for spot welding and have been widely used. Spot welding, however, is not confined to the soft low carbon steels but is now being applied to the more usual structural alloy steels; much progress has been made along this line and much more will certainly be made in the future.

The above describes the operation of making a single weld. Spot welds, however, need not be made singly. They may be made in series, in which the current passes through two or more sets of contact surfaces and makes a weld at each place. Spot welds may also be

made in parallel, where the current divides and makes a number of welds at the same time. Spot welding is not confined to the joining of only two parts; multiple-ply welds can be made, joining as many as ten pieces if desired.

Designing for spot welding has not progressed as rapidly as is the case with other processes. Design standards are not so generally available and much research work is necessary to establish them. However, one factor simplifies this problem — it is so easy to make spot welds that it is often simpler to make surplus welds than elaborate calculations.

Interrupted Spot Welding

Spot welding is generally confined to rather thin materials in the sheet metal range. However, new developments have been made in the so-called interrupted spot welding (see R. S. Pelton's article in METAL PROGRESS for July) whereby the spot is made with a number of current impulses. By this means very heavy materials have been spot welded, in some instances as thick as one inch.

Projection Welding is a variation of spot welding in which a contact is concentrated at a small area where an embossment is pressed in one member. Flat dies are often used and when the pressure is finally applied the embossed part is pressed flat and little or no evidence of welding remains. Projection welds are often made in groups, thereby increasing production.

Seam Welding is a rapid and efficient production process of joining two sheets or strips wherein a current is passed through them by means of circular or roll electrodes. Due to the electrical impulses received, a seam weld is usually a series of overlapping spot welds, the size of the spots and the amount of the overlapping depending upon operating conditions. Interrupted current may be obtained by means of the thermionic controls. It should be pointed out that if the spots do not overlap, the weld is a series of spot welds, even though made with the roll electrode. Conversely, if a weld is a series of overlapping spots, even if made by means of ordinary spot welding electrode, the weld is a seam weld.

Seam welding can also be done in series or in parallel and can be effected with segmental wheels, thereby providing points at which no welding obtains.

Resistance Butt Welding — A resistance butt weld is one made by passing current through two members, the ends of which are in contact at the time the current is switched on. The resistance at the contact surfaces causes heating at that point and the temperature is gradually raised until a sufficient degree of temperature is obtained, when the weld is consummated by the application of pressure. This process is slow and requires large currents; in special cases it has been superseded by flash welding. The size of pieces which can be butt welded by resistance is probably limited only by the amount of current and the size of machine available.

Flash Welding — A flash weld is one made by clamping two members in a machine in such a way that they are not in contact at the time the current is applied. After the current has been turned on, the pieces are moved together and when the potential is able to bridge the distance between the parts, an arc jumps from one to the other at the high points. This arcing spreads and continues until the gap between the two pieces attains electrical uniformity, when the weld is consummated by the application of pressure.

Flash welding, which is a combination of arc and resistance welding, uses far less current and very much less time than the butt welding described previously. It is used for thin sections, such as automobile body sheet, or for very heavy sections with many square inches of cross sectional area. The range of this process is therefore greater than that of any of the other resistance processes. Flash welding may also be used on almost all ferrous metals. While not as rapid as spot welding, it is nevertheless capable of rapid production and is one of the most used of the welding processes.

There are a number of other processes of lesser importance which will not be mentioned, although one never knows whether or not one that is relatively little used today may not be of the greatest importance tomorrow.

Relation of Costs and Design

It will be seen from the foregoing that welding is a very vigorous child. However, before it reaches maturity a more complete understanding of its possibilities and peculiarities must be obtained. Designs for welded parts are sometimes not all that they should be, yet if failure occurs, the cause is laid to bad welding. In most cases the failure *(Cont. on page 560)*

"YOU COVER A WIDER RANGE AND WELD 15% TO 20% FASTER WITH THE NEW 'SHIELD-ARC SAE'—

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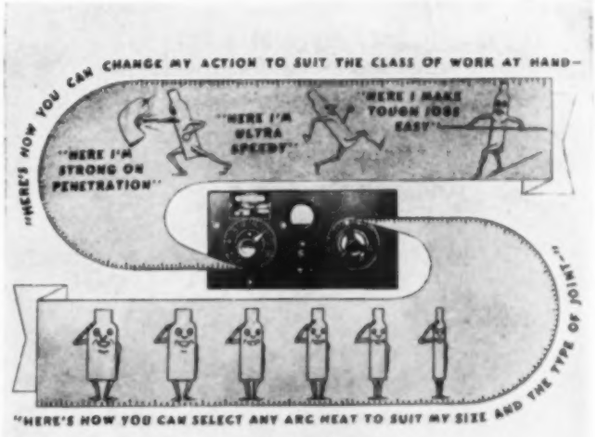
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"HERE I'M STRONG ON PENETRATION"
"HERE I'M ULTRA SPEEDY"
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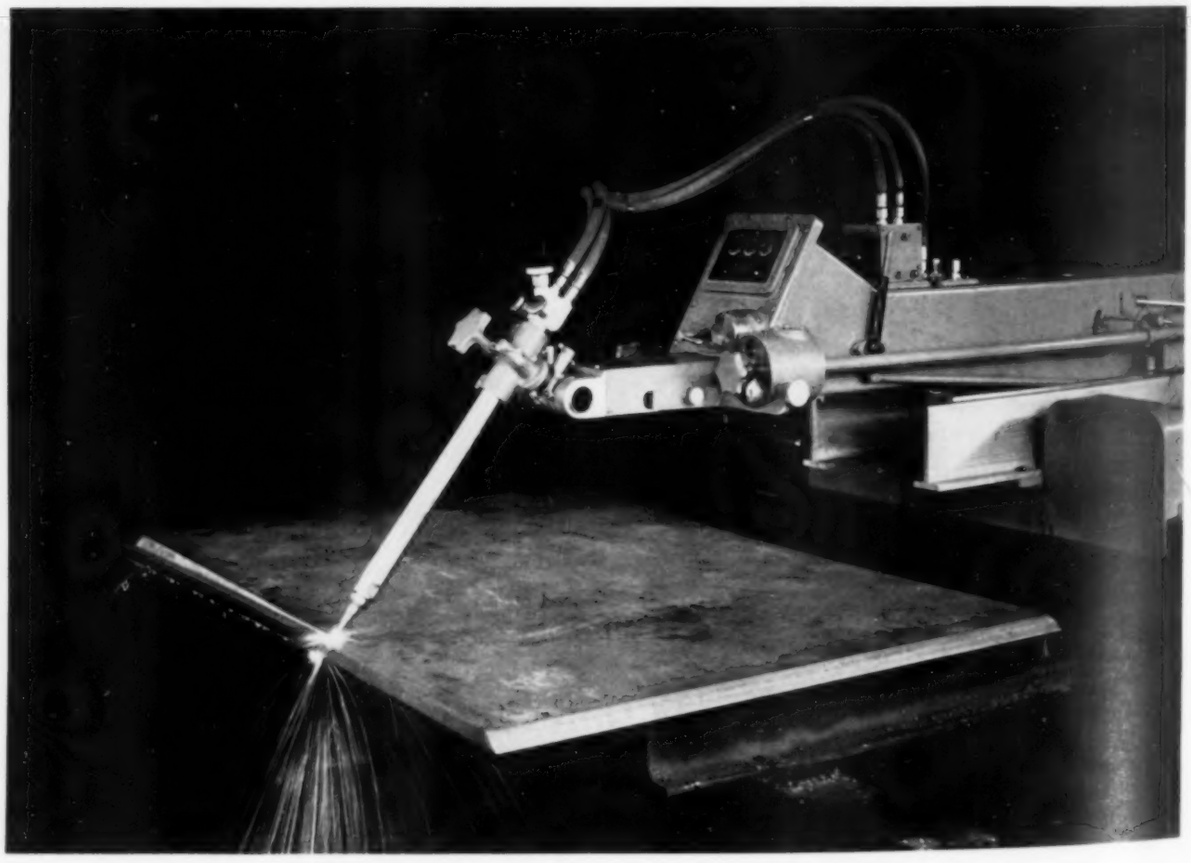
is due to poor design. If the design is correct, even mediocre welding will generally not cause failure; if the design is improper, however, first-class welding cannot insure success.

Often welding is condemned because it is claimed that the cost is too great. Here again the fault is largely one of design. Far more weld metal may be used than is necessary, or corners are welded when flanging, forming, or pressing should be done. If the part were designed correctly so that full advantage could be taken of all the production possibilities, and proper methods were used in the shops, it would very frequently be found that the welded construction was not more expensive than some other forms. Today, welding has demonstrated that it is amply strong to do the job at hand; tomorrow it will demonstrate more convincingly that it can do this more cheaply than can be done by any other method.

In attacking any design problem the designer should erase from his mind all the limitations of other methods of construction and seek to attain his object in the simplest, cheapest, and best way with the new medium at his command. There are two methods of attack — one, which might be called the evolutionary method, is wherein one little part is changed today and some other part is changed tomorrow and at the end of a few months or years a completely welded design is evolved. The other might be called the revolutionary method of attack, wherein the designer goes directly to the ideal construction. This method may be more of a shock to the conservative mind than the former, but eliminates the transition period during which generally the full benefits of welding are not obtained.

Much more rapid progress in the future should be expected by reason of the work now being done by the Engineering Foundation Welding Research Committees and the invigorated American Welding Society. The highest praise should be given to the very fine cooperative spirit with which this work is being carried into effect.

While Everyone Is Familiar With the Fact That an Oxy-Acetylene Flame Will Cut Intricate Shapes Out of Steel of Almost Any Thickness, the Ability to Cut on an Angle Has Usually Been Thought of as Restricted to Machine Tools. Photo by John Hans for Linde Air Products Co.



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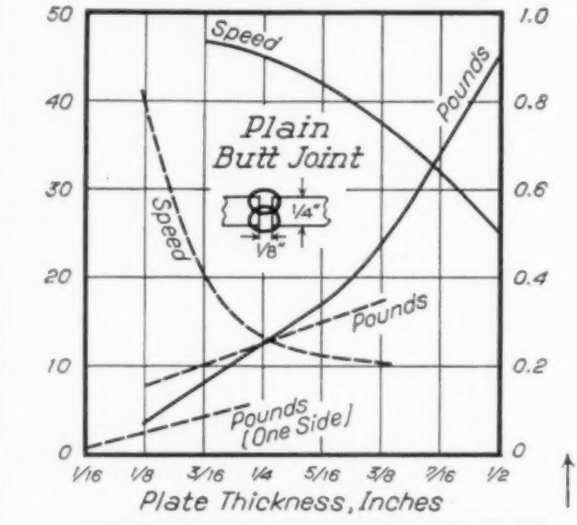
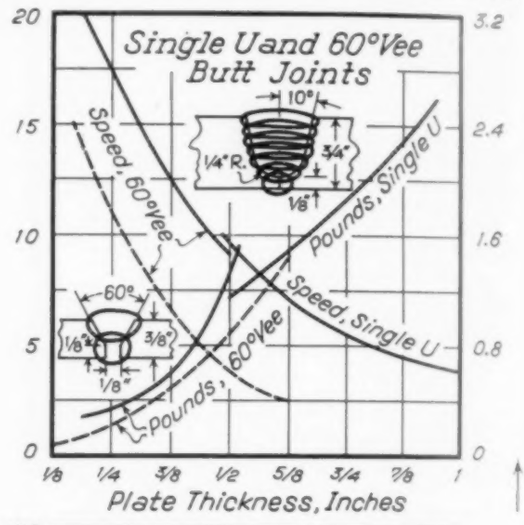
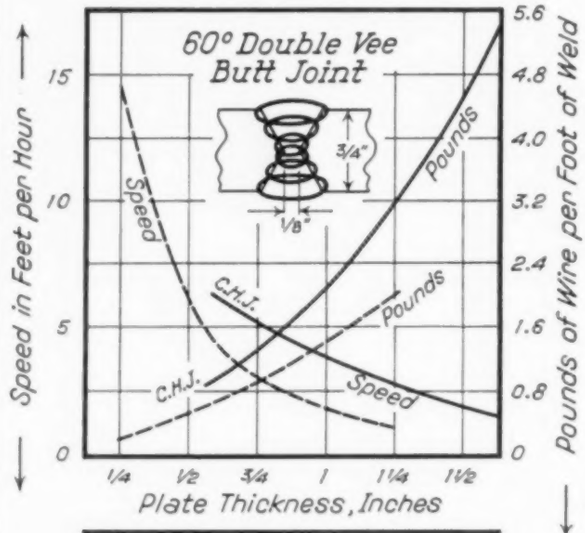
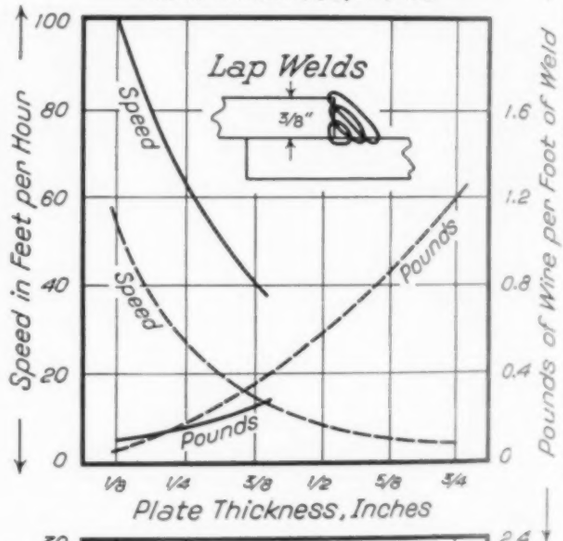
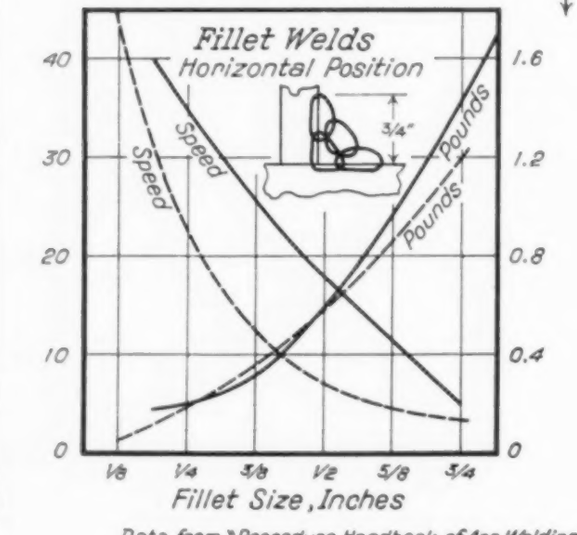
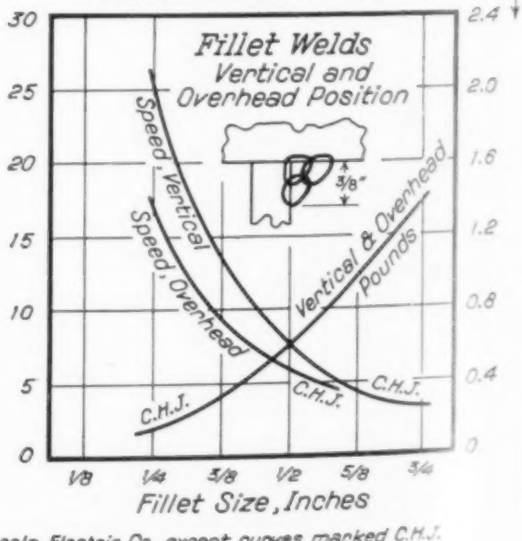












Data from "Procedure Handbook of Arc Welding", Lincoln Electric Co., except curves marked C.H.J. from "How to Weld 29 Metals" by Charles H. Jennings, Westinghouse Elec. & Mfg. Co.

Developments in Non-Ferrous Alloys (Heavy Metals)

By D. K. Crampton
Director of Research
Chase Brass & Copper Co.
Waterbury, Conn.

Rise of Die Castings, Not Only Zinc Base and Aluminum Base, but Also Copper Base Is a Notable Recent Movement. Photo by Irving Browning, N. Y.

STEADY PROGRESS rather than sensational developments characterize the non-ferrous alloy field in general. Even when some outstanding new alloy, process or application is brought to the commercial stage at a given time, this usually comes as a result of relatively slow evolution, possibly covering several years. The comments here made are therefore to be taken as descriptions of developments still in process or which may have been described elsewhere quite recently.

Judging by the number and quality of the articles in the technical literature on bright annealing of all types of alloys, as well as by the number of patents covering furnaces, handling mechanisms, operating procedures and atmospheres, this appears to be a development of the greatest practical significance. It is especially interesting in view of the fact that not so many years ago it was felt by many well-informed people that such annealing processes while of great technical interest were hardly feasible economically. The cost of maintaining the required atmosphere, together with the increased cost of a suitable type of furnace, generally led to predictions that such processes would be used in a relatively small percentage of cases and only where a considerable premium for the product was warranted. But the distinct indication at present is that the use of bright annealing for a majority of commercial metals and alloys is decidedly on the increase and that before many years it may become the standard procedure rather than the exception. While the cost is still high and probably will remain so as compared to ordinary oxidizing annealing, it is quite evident that the general consuming interests are satisfied to have it so and feel the product is worth the extra cost.

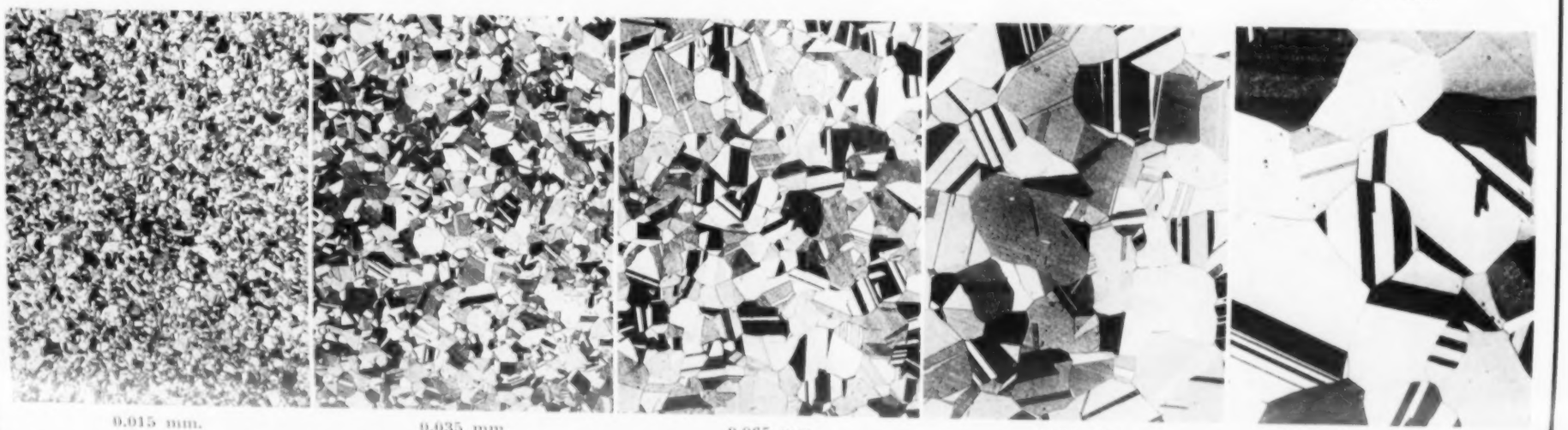
In this connection it is interesting to note the general appreciation of the necessity for precise control and balance between atmosphere, temperature and time. The latter factor especially is of paramount importance in the

Standards for Estimating Grain Size (Non-Ferrous)

American Society for Testing Materials Standard E2-36 (copyrighted) for annealed materials such as brass, bronze, nickel silver

Actual diameter of average grain is noted; Magnification of micros: 75×

0.010 mm. 0.025 mm. 0.045 mm. 0.090 mm. 0.150 mm.



0.015 mm. 0.035 mm. 0.065 mm. 0.120 mm. 0.200 mm.

bright annealing of many alloys, as for instance, the brasses of less than about 85% copper. Due to the volatilization of zinc, it has been found impossible to really bright anneal these alloys in any atmosphere, even a vacuum, if they be held at the annealing temperature for an appreciable time. However, satisfactory results can be attained with strip type operations where the material is at the desired temperature an extremely short time. This has naturally been a very important factor in the design of furnaces for this operation.

The use of water cooled molds in the casting of cakes and billets for hot or cold working is increasing. This trend is a result of the realization that such molds not only tend to give a cleaner, sounder casting, but simultaneously a lower mold cost per pound cast. This is because there is relatively little upkeep on such molds whereas the maintenance and replacement of the initially cheaper air cooled molds is in many instances exceedingly high.

New Production Processes

A large amount of laboratory and commercial work continues on several processes for producing sheet, rod or tubing direct from the melt, thus eliminating many intermediate mechanical operations. For instance, the continuous production of strip or sheet in long coils by direct freezing between rolls is noted. This process has been in the state of development for several years and some difficulties have yet to be completely worked out. It still gives great promise of being a most interesting procedure and there appears no good reason why, with continued effort, further important commercial applications will not result.

Likewise, the experimental development of continuous casting of rods and bar shapes from a melt by withdrawal through a die or forming chamber is being steadily pursued. The difficulties in the way of successful large-scale operation have for years seemed almost insurmountable, but success now seems at hand and commercial exploitation probably not very far in the future.

Applications of powder metallurgy continue to increase. Rather surprising quantities of copper and certain other non-ferrous metals are now being produced in powder form for the manufacture of sintered bushings and other articles. One of the interesting new applications introduces certain elements of high melting point in powder form with a suitable proportion of the base metal in powder form, and the sintered briquettes used to make the addition to the final alloy. Certain combinations can be effected in this manner which are virtually impossible by the procedures that have heretofore been used.

It seems in order to speak briefly of corrosion testing methods. Corrosion is in itself one of the major problems of the metal industry and various estimates of the annual damage by corrosion run into figures which are truly astounding. Corrosion testing methods have progressed, and as indicated in a recent symposium by the American Society for Testing Materials, procedures are now available so that tests carefully carried out and sensibly interpreted can be relied upon to give fair indications of the relative performances expected from various alloys and following various treatments.

New methods of welding and various types of alloys for filler rod continue to arrive. Not only fusion welding but brazing, soldering and resistance welding methods have been the subject of a series of important developments. The very large number of recent patents on all phases of welding is another evidence of the importance attached to these processes. It is impossible to speak of all of these but one of the most interesting and worth while has to do with welding tips for spot welding and rollers for seam welding made from various alloys hardened by precipitation.

Such electrodes require a combination of properties not ordinarily found in any of the common work hardening materials. It is essential that they show strength and hardness at moderately elevated temperatures, resistance to softening and flowing, resistance to oxidation and pitting by arcing, high electrical conductivity, high thermal conductivity, ability to be produced in the forms and sizes necessary, and capability of ready machining to finished size. Among those found most successful are several variations of chromium-bearing copper alloys. More recently copper-zirconium-cadmium alloys have been developed which appear most interesting. Many others are being brought out commercially or are still in the experimental stage.

In the electrical industry developments include welded joints in large bus bars, making for marked improvement in appearance, low installation cost and high joint efficiency. The welding of copper has heretofore been consid-

Metal Progress, 1937 Reference Issue, Page 570

Extruded Billets of Copper Alloy Being Sawed to Length, Prior to Piercing and Rolling Into Seamless Tubes. Photo courtesy Chase Brass & Copper Co.

ered an extremely difficult problem and is still one which requires maximum skill and high grade deoxidized materials. However, a welding rod and technique have been developed to permit of such construction and there are now in the process of being built at least two very large installations using a welded tubular bus.

The production of relatively thin and wide sheet copper by continuous electrodeposition on rotating drums has been brought to the commercial stage. One process is in present use and at least one other gives promise of being successfully used in the near future. These methods have an inherent advantage over the ordinary rolling procedure as far as economy of production is concerned. Along with the commercial development has occurred a considerable improvement in the quality of the finished strip.

Two very interesting applications of copper are in finned tubes for convectors and heat exchangers. While the fundamental idea involved is not new, the advantages of finned tube construction have resulted in many carefully planned experimental programs to develop the greatest possible capacity for heat interchange per unit of weight, and at the lowest cost of fabrication. One recent development is an ingenious method of rolling a fin from the body of an ordinary seamless tube. In the special machine for forming this fin, the tube meets successively a series of grooves so designed as to produce each a higher and thinner fin. The particular advantage of this type of construction is that there are no joints between the tube and the fin, thus eliminating one source of loss sometimes present in jointed structures of various types.

Another more recent and quite revolutionary innovation in this same field is about to be commercially offered. Careful research has shown that, all other things being equal, the total amount of heat which can be dissipated from a finned tube increases markedly with increase in the ratio of width of the fin to the diameter of the tube itself. While there have been numerous methods of fabricating finned tubes, none previously used has ever been commercially successful in producing fins having a width (radial depth) greater than approximately one-half the tube diameter. With the new method referred to, there is practically no limit; the assembly method is also new and fundamentally different from previous ones and insures a joint of high thermal efficiency.

The marked increase in use of copper water tube for plumbing and numerous other purposes has continued steadily for a number of years. In this connection a development of primary importance is the production of one-piece

wrought copper tees to take the place of two-piece wrought tees or one-piece cast tees. At least two methods, which are ingenious in the extreme, have been developed commercially for producing such wrought tees, and these result in a product of lowest possible weight, smooth surface, high strength and capacity for large water flow.

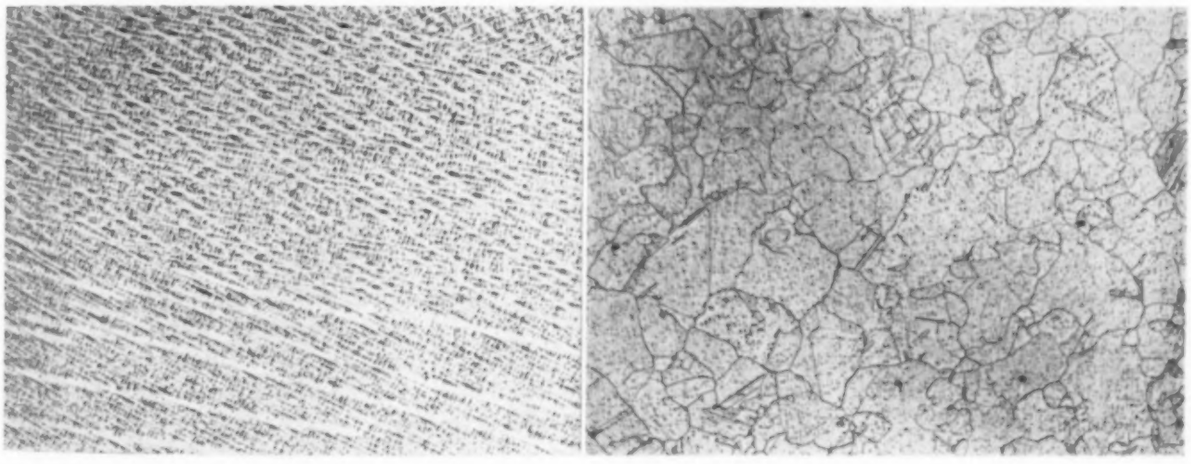
In the field of condenser tubes and heat exchanger tubes, several new things are worthy of mention. One of the more important is bimetallic or two-layer condenser tubes, one layer being a copper alloy designed to be highly resistant to sulphur-bearing oils and vapors, and the other layer highly resistant to corrosive waters. This is a real advance, as heretofore no single commercial alloy has been available showing a really high degree of resistance to both of these fundamentally different types of corrosion.

Another innovation in the condenser tube field is one where an element hitherto classed as a nuisance element has been turned to commercial advantage and helps to solve a very old problem. For instance, the element antimony had for many years been considered highly detrimental in many copper products and every effort was made to eliminate it. However, it has been found that this supposedly objectionable metal has a most interesting and powerful effect in reducing the tendency of various yellow brasses to corrosion of the type known as dezincification.

For many years producers of copper alloys have considered that the only way to obtain readily machinable alloys was to incorporate lead in as great a percentage as the size of the ingot and proportions of other elements would permit. It has recently been found that two more of the so-called nuisance elements are not only not as objectionable as heretofore thought, but can even be turned to good use. These elements are tellurium and selenium, which have now been incorporated in various copper alloys and which in some instances show an even more powerful effect on machinability than lead. Alloys containing these elements will probably soon be offered commercially.

In the lead alloys, from a number of interesting developments, one especially is of wide interest and great present commercial importance, namely creep resistant alloys. Until rather recently wherever lead was desired to carry any sizable loads, this was obtained by hardening it with a certain quantity of antimony or tin. While lead-antimony and lead-tin alloys show marked improvement over commercially pure lead in some ways, they have not been as universally satisfactory as might be wished; there are even instances on record where these alloys were detrimental.

Systematic investigation of certain commercial leads showed that a stiff lead alloy is not necessarily one more resistant to creep. In fact, as a rule the opposite was found to be true; the stiff leads might stand a considerable overstrain for relatively short periods of time, but they were unsatisfactory for long sustained,



Microstructure of New Free Cutting Bronze Utilizing 0.75% Tellurium, Formerly Thought to Be a Nuisance Element. Left, as cast; right, cold drawn and annealed; both at 50 diameters

relatively low loadings. Marked differences in the behavior of some commercial leads led to the important finding that all grades of lead containing appreciable quantities of copper showed a superior resistance to creep, when compared to fully refined leads free of copper. However, by adding copper to these fully refined leads, it was possible to raise the creep resistance of such without affecting adversely the other properties like corrosion resistance and ductility. Certain new brands of lead have therefore been made by the addition of copper to fully refined commercial lead, and the probability is strong that the use of such leads will increase markedly.

Interesting discoveries about silver and silver alloys are resulting in a greatly increased commercial use of this semi-precious metal, and an extensive and systematic series of researches is being sponsored by principal American producers. One of the more important uses is for electrical contacts. It has been found that silver gives excellent performance as a facing material for switch blades, bus bar connections and relays. Silver alloys are also used, including certain ones formed from metal powders, as for instance, silver-nickel, silver-graphite and silver-molybdenum.

Use of silver brazing or silver soldering alloys increases steadily. There are now available a large number of silver-base alloys for this purpose having a wide range of melting points and high corrosion resistance, combined with high tensile strength and toughness.

In the chemical field an increasing amount of fine silver is being used because of its high resistance to corrosion by chemicals such as organic acids and strong alkalies. Recently some very large pieces of equipment have been fabricated, and the indication is that there will be a further extension of such use of fine silver. The advent of duplex metal with a heavy layer of silver on copper or iron and suitable methods for welding these have been instrumental in increasing the use of silver in chemical fields.

The whole problem of bearings is being intently studied from all angles by producers, consumers, and lubrication engineers. Ideas and usages are in a state of flux; the conditions are noted in various articles and editorial notes in past issues of METAL PROGRESS.

There have been many recent experimental investigations of new tin-base alloys and others are now under way. Much attention is being given to the improvement in the mechanical properties by addition of such elements as silver, nickel, copper, aluminum, manganese and bismuth. Copper has been found to be a very desirable alloying element for tin, 1% of copper increasing the tensile strength by approximately 120%. However, the element which seems to have the greatest effect on the mechanical properties is bismuth; alloys with up to 5% or more are capable of production by rolling and would appear to be commercially feasible. Such alloys in the self-annealed condition show tensile strengths of the order of 11,000 psi. as compared to perhaps 2500 psi. for pure tin. Further, while annealing at 250° F. causes a marked reduction in the tensile strength of pure tin, this temperature has no softening effect on the tin-bismuth alloy. It appears that such improvements in the properties of a material of such inherently low strength but of so great utility in other directions, could not help but be of considerable practical significance.

While zinc of extreme purity is not really new, a greatly increased demand for it has resulted in much study directed to perfecting the manufacturing processes. Any such development resulting in large scale commercial production of a metal of 99.99+% purity is certainly of major technical importance. In addition to the electrolytic processes first used to obtain this extra high grade zinc, better than "four nines," there is now a pyrometallurgical process whereby zinc of equal purity is produced by redistillation.

These very pure zincs are of practical importance in three fields. First, zinc-base die castings require the very highest purity materials available in order to overcome troubles experienced in former years with swelling and distortion. Second, in the galvanizing field, especially electro-galvanizing, a very high purity zinc is found to have markedly greater ductility and therefore the ability to stand more severe bending. Third, in certain brasses that are to be hot worked, the difference between ordinary high grade and special high grade zinc might make a difference between success and failure.

Taken as a whole, the progress in production, testing and uses of non-ferrous metals is a source of great satisfaction to the metallurgist, as well as to those interested in the commercial exploitation of these products. It is confidently expected that the present rate of progress will continue over a considerable time and many new and highly important innovations be brought out.

Progress in Light Alloys

By A. J. Dornblatt

Washington, D. C.

55 Lb. of Pickaninny and 21 Lb. of Aluminum.
Beer Barrel and Photograph by Aluminum Co. of America

CERTAIN current activities in the light metals field and related aircraft metallurgy developments were dealt with briefly in editorial reviews appearing in METAL PROGRESS in October 1936 and January 1937. In what follows it is proposed to outline some other recent developments, including the more notable foreign ones, so that a general idea of present trends may be obtained.

Aluminum and magnesium, of all the metallic elements, are the only two elements inherently light in weight, chemically stable, commercially obtainable and manufactured on a large scale. Both form alloys possessing adequate strength for use in engineering construction, and both possess certain other features which, besides the lightness of the alloys, help account for their use in a rapidly increasing tonnage. In fact, the successful efforts being made abroad to increase the output and use of the light metals, substituting them wherever possible for imported metals, form one of the most striking of present trends.

Aluminum has just celebrated the 50th anniversary of the discovery by Charles M. Hall of the electrolytic process for reduction which is still, basically, the process in use throughout the world. Magnesium, industrially speaking, has just come of age. Yet, despite the comparative youth of both these metallurgical marvels, their production and use has vastly increased. Statistics on world production show that, in the case of aluminum, the production has more than doubled each decade since 1910. The 1936 production reached an all-time high of 357,600 metric tons, of which the United States produced 102,000, leading all other nations but with Germany a close second. Estimates on the world magnesium production in 1936 agree that it was a boom year but vary in regard to the actual values, which range from 15,000 to over 50,000 tons. Germany probably is the leading producer, with the United States coming second or third in order.

Some technologic developments slowly brought to fruition will now be briefly reviewed.

A French process for the manufacture of aluminum is said to produce regularly 99.99%

Typical Mechanical Properties of Aluminum Alloys

Data as furnished by Research Laboratory, Aluminum Co. of America

Wrought Alloys

Wrought Alloy and Temper	TENSION				HARDNESS	SHEAR Psi.	FATIGUE
	Yield (a)	Ultimate Strength Psi.	Elongation % in 2 In. Sheet (b)	Elongation % in 2 In. Bar (b)	(d)	(e)	(f)
2S-O	5,000	13,000	35	45	23	9,500	5,000
2S-¼H	13,000	15,000	12	25	28	10,000	6,000
2S-½H	14,000	17,000	9	20	32	11,000	7,000
2S-¾H	17,000	20,000	6	17	38	12,000	8,000
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	6,000	16,000	30	40	28	11,000	7,000
3S-¼H	15,000	18,000	10	20	35	12,000	8,000
3S-½H	18,000	21,000	8	16	40	14,000	9,000
3S-¾H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
4S-O	10,000	26,000	20	25	45	16,000	14,000
4S-¼H	22,000	30,000	10	17	52	16,000	14,500
4S-½H	27,000	33,000	9	12	63	18,000	15,000
4S-¾H	31,000	37,000	5	9	70	20,000	15,500
4S-H	34,000	40,000	5	6	77	21,000	16,000
11S-T3	42,000	49,000	..	14	95	30,000	.....
17S-O	10,000	26,000	20	22	45	18,000	11,000
17S-T	37,000	60,000	20	22	100	35,000	15,000
17S-RT	47,000	65,000	13	..	110	36,000	.....
Alclad 17S-T	33,000	56,000	18	..	...	32,000	.....
Alclad 17S-RT	40,000	57,000	11	..	...	32,000	.....
A17S-O	8,000	22,000	24	27	38	15,000	.....
A17S-T	24,000	43,000	24	27	70	25,000	13,500
24S-O	10,000	26,000	20	22	42	18,000	.....
24S-T	44,000	68,000	19	22	105	41,000	16,000
24S-RT	55,000	70,000	13	..	116	42,000	.....
Alclad 24S-T	41,000	62,000	18	..	...	40,000	.....
Alclad 24S-RT	50,000	66,000	11	..	...	41,000	.....
51S-O	6,000	16,000	30	35	28	11,000	6,500
51S-W	20,000	35,000	24	30	64	24,000	10,500
51S-T	40,000	48,000	14	16	95	30,000	10,500
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S-¼H	26,000	34,000	12	18	62	20,000	18,000
52S-½H	29,000	37,000	10	14	67	21,000	19,000
52S-¾H	34,000	39,000	8	10	74	23,000	20,000
52S-H	36,000	41,000	7	8	85	24,000	20,500
53S-O	7,000	16,000	25	35	26	11,000	7,500
53S-W	20,000	33,000	22	30	65	20,000	10,000
53S-T	33,000	39,000	14	20	80	24,000	11,000

Sand Cast Alloys

SAND CAST ALLOYS	Tension (c)			Compression (g)		Hardness	Shear Psi.	Fatigue	Density
	Yield (a)	Ultimate Strength Psi.	Elongation % in 2 In. (b)	Yield (a)	Ultimate Strength Psi.	(c)	(e)	(f)	Lb per Cu. In.
12 and 212	14,000	22,000	2.0	14,000	64,000	65	20,000	7,500	0.102
43	9,000	19,000	6.0	12,000	.....	40	14,000	6,500	0.096
47 (h)	11,000	26,000	8.0	11,000	.....	50	18,000	6,000	0.095
108	14,000	21,000	2.0	14,000	62,000	55	20,000	8,500	0.099
109	18,000	24,000	1.5	20,000	64,000	75	20,000	10,000	0.105
112	14,000	23,000	1.5	17,000	62,000	70	20,000	8,500	0.103
122-T2	20,000	25,000	1.0	20,000	62,000	75	21,000	9,500	0.106
122-T61	30,000	36,000	1.0	43,000	96,000	100	29,000	.....	0.106
142	24,000	28,000	1.0	31,000	82,000	80	24,000	8,000	0.101
142-T61	32,000	37,000	0.5	47,000	77,000	100	32,000	8,000	0.101
142-T571	28,000	32,000	0.5	34,000	79,000	85	27,000	8,000	0.101
195-T4	16,000	31,000	8.5	16,000	.....	65	24,000	6,000	0.100
195-T6	22,000	36,000	5.0	25,000	.....	80	30,000	6,500	0.100
195-T62	31,000	40,000	2.0	38,000	85,000	95	31,000	7,000	0.100
214	12,000	25,000	9.0	12,000	.....	50	20,000	5,500	0.095
216	15,000	27,000	6.0	16,000	.....	60	23,000	.....	0.094
220-T4	25,000	45,000	14.0	26,000	.....	75	33,000	7,000	0.092
A334	16,000	25,000	2.0	22,000	73,000	65	24,000	.....	0.099
355-T4	20,000	30,000	5.0	23,000	87,000	60	28,000	.....	0.097
355-T6	25,000	35,000	3.5	37,000	94,000	80	30,000	.....	0.097
355-T51	23,000	28,000	1.5	24,000	50,000	60	22,000	6,500	0.097
A355-T51	24,000	28,000	1.5	24,000	54,000	65	22,000	8,000	0.099
A355-T59	21,000	25,000	2.0	21,000	48,000	60	21,000	8,000	0.099
356-T4	16,000	28,000	6.0	18,000	84,000	55	22,000	.....	0.095
356-T6	22,000	32,000	4.0	22,000	87,000	70	27,000	8,000	0.095
356-T51	20,000	25,000	2.0	22,000	56,000	60	18,000	6,000	0.095
645	20,000	29,000	4.0	20,000	70,000	70	22,000	7,500	0.106

For all Alcoa alloys, wrought and cast:

Young's modulus of elasticity ..... 10,300,000 psi.
Modulus of rigidity in shear ..... 3,800,000 psi.
Poisson's ratio 0.33
Bearing strength is equal to 1.8 times the tensile strength, provided the edge distance is not less than twice the diameter of the hole.

Note (a): Yield strength is the stress producing a permanent set of 0.2% the initial gage length.

Note (b): Dimensions of test pieces: Sheet $\frac{1}{16}$ in. thick; wrought and cast bars, 0.505 in. dia. Elongation varies with the form and size of test specimen. For bar, rod, and wire (except material from which a flat specimen can be taken) and for sub-size round specimens the gage length for the measurement of elongation is equal to four times the diameter. For black specimens the gage length equals four times the width.

Note (c): Tension and hardness values for cast alloys determined from standard half-inch diameter tensile test specimens, individually cast in green sand molds and tested without machining.

Note (d): Brinell hardness determined with 500-kg. load and 10-mm. ball.

Note (e): Shearing strengths are single-shear values obtained from double-shear tests.

Note (f): Endurance limits based on specimens withstanding 500,000,000 cycles of completely reversed stress using the R. R. Moore type of machine and specimen.

Note (g): Compression tests were made on specimens with $l/r = 12$. Where no value for ultimate strength is shown, specimens flattened without failing; others failed in shear.

Note (h): Properties of "modified" alloy.

pure metal, and on occasion has produced 99.998% pure aluminum. It resembles the Hoopes process but uses a bath which operates at a lower temperature (1300 to 1400° F.). Special purity aluminum is notable for its extraordinary corrosion resistance, low temperature of recrystallization, and high electrical conductivity. It can be cold rolled from the billet to sheet.

Reports from abroad state that savings up to $4 per ton of alumina can be effected by substituting a continuous-pressure apparatus for decomposing bauxite with alkali in place of the intermittent autoclave. It is also claimed that alumina can be produced, for use in the production of aluminum, from alkaline German clays at a price comparable with that of alumina made from imported bauxite.

Improvements in Aluminum Alloys

In this general survey, no attempt will be made to give specific information on the characteristics of the more important commercial light alloys since excellent summaries have appeared in the recent literature. In this connection the reader's attention is invited to J. B. Johnson's article on "Light Metals for Aircraft" in October 1935 METAL PROGRESS and to the paper on "Alloys of Aluminum and Magnesium" by E. H. Dix presented at the March 1936 Symposium of the American Society for Testing Materials on High Strength Constructional Metals. Historical aspects are treated in John A. Gann's paper "Magnesium, the Growth of an American Industry" which appeared in METAL PROGRESS for April 1932, and in Junius D. Edward's article "Contributions of Aluminum to Metallurgical Progress" in METAL PROGRESS, February 1936.

The principal structural alloy is still the 17S (duralumin), but for applications, as in aircraft, requiring maximum strength this alloy has been largely superseded by a stronger variety, higher in magnesium. The development of this alloy, known as 24S, has been described by T. W. Bossert in January 1937 METAL PROGRESS. An alloy of recent development being used primarily for rolled structural shapes is the magnesium-free, modified duralumin designated 27S, characterized by a high yield point and good corrosion resistance.

Two alloys of moderate strength, possessing high inherent corrosion resistance, have lately come into general use. One is the aluminum-magnesium-silicon alloy 53S, of carefully controlled composition, notable for its excellent resistance to corrosion in all tempers. An aluminum-magnesium-chromium alloy, designated 52S by the Aluminum Co. of America, is the other. It is notable for its resistance to salt water and marine atmosphere and its high endurance limit. In the strain hardened condition it is finding wide usage in marine, railroad, bus, and architectural construction.

Considerable progress has resulted from better control of ingot segregation and improved forging practice. For instance, the propeller forging for the 1931 Schneider cup winner weighed 350 lb. in the rough condition and 85 lb. after machining, whereas present day propeller forgings may weigh 96 lb. before machining and 70 lb. finished; not only is machining reduced to a minimum, but present practice produces a better macrostructure and airfoil cross-section. In view of improvements in technique, certain alloys heretofore considered unforgeable have been re-examined and from England comes a report of an improved alloy of the high zinc type, developed originally by Dr. Rosenhain and co-workers. S. L. Archbutt and A. G. C. Gwyer report on this alloy and other British advances in aluminum alloys (abstracted in METAL PROGRESS last month).

The original magnalium alloys, which are aluminum with magnesium additions, have been similarly reconsidered and the alloys with from 2 to 10% magnesium are important alloys today. The 7% alloy is extensively used abroad, but little use of such alloys in the wrought condition prevails in this country.

A development of considerable potential importance is the successful operation on a small scale of the Hazlett process for direct production of sheet from molten aluminum by casting between revolving chill rolls. Commercial production at the moment seems only to await installation of necessary equipment.

The cladding of wrought, high duty alloys with corrosion resistant, integrally bonded, pure aluminum (that is, alclad material), extended the field of usefulness of the duralumin type of alloy where, as in thin gage material for aircraft construction, there was need for greater resistance to corrosion. A stronger protective skin has been developed, consisting of a corrosion resistant alloy, instead of the weaker high purity aluminum, and finds some use abroad.

To permit the use of aluminum alloys in corrosive environments research has also been

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directed successfully into other channels. Processes have been developed for producing a protective oxide film which affords an excellent base for paints and ornamental finishes. The anodic oxidation method is widely used, conditions being varied to develop a surface of the desired characteristics. In some instances, for example, the essential characteristic desired may be wear resistance, or a high optical reflectivity. Protection may also be obtained by chemical dip processes, and the offer of a 25,000-franc prize for the best process of this kind by the Bureau International des Applications de L'Aluminium is stimulating additional researches.

Development of free-machining wrought alloys of the duralumin type has afforded a new outlet for such alloys in screw machine products. A picture of the situation in this field can be obtained from the articles in METAL PROGRESS by L. W. Kempf and W. A. Dean, July 1935; L. W. Kempf and A. Hartwell, December 1936; and Hans Diergarten's comprehensive review in the issue of August 1937.

Fabrication of aluminum alloy structures has been facilitated by reason of recent developments in seam and spot welding, as brought out by D. I. Bohn in METAL PROGRESS for July 1937. Co-operative work with the manufacturers of welding equipment and metal fabricators has led to lower costs, improved appearance and a superior structural result with modern welding equipment now being used for many types of manufactured commodities.

Popularity of Heat Treated Castings

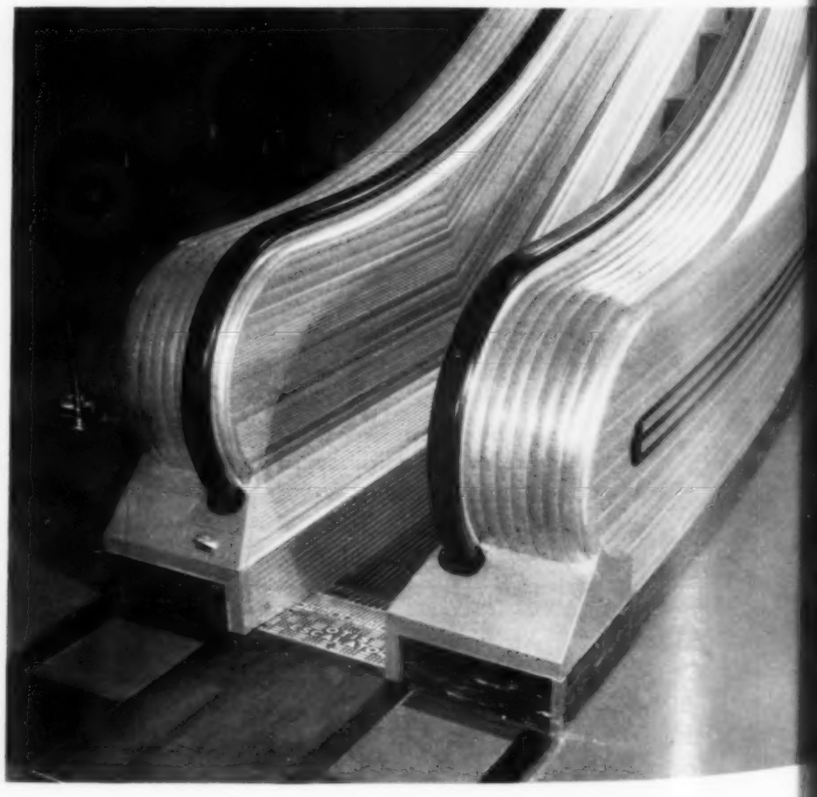
Developments in aluminum casting alloys worthy of note appear to be the increasing use of heat treated castings, of grain refining agents such as titanium, and the development and widening use of the readily cast alloys of aluminum and silicon and the strong, corrosion resistant alloys of aluminum and magnesium.

Heat treatment of castings is favored because it produces a higher ratio of yield to tensile strength, a higher ultimate tensile strength, and superior ductility and toughness compared to the alloy as cast. The aluminum-copper casting alloys represent the largest tonnage of these heat treated castings, but there is an increasing use of the Al-Si-Mg (356) and Al-Si-Mg-Cu (355) alloys for complicated shapes. The alloys containing silicon are generally easier to cast, less liable to crack on quenching from high temperatures during heat treatment, and have generally better foundry characteristics than the earlier aluminum alloys hardened with copper.

The 12% silicon alloy extensively used abroad may be improved by heat treatment if minor additions of magnesium and manganese are made. Although it requires a special modification treatment, this variety is said to retain the valuable casting characteristics of the binary alloy while in addition it affords a combination of strength, corrosion resistance and lightness that is remarkable.

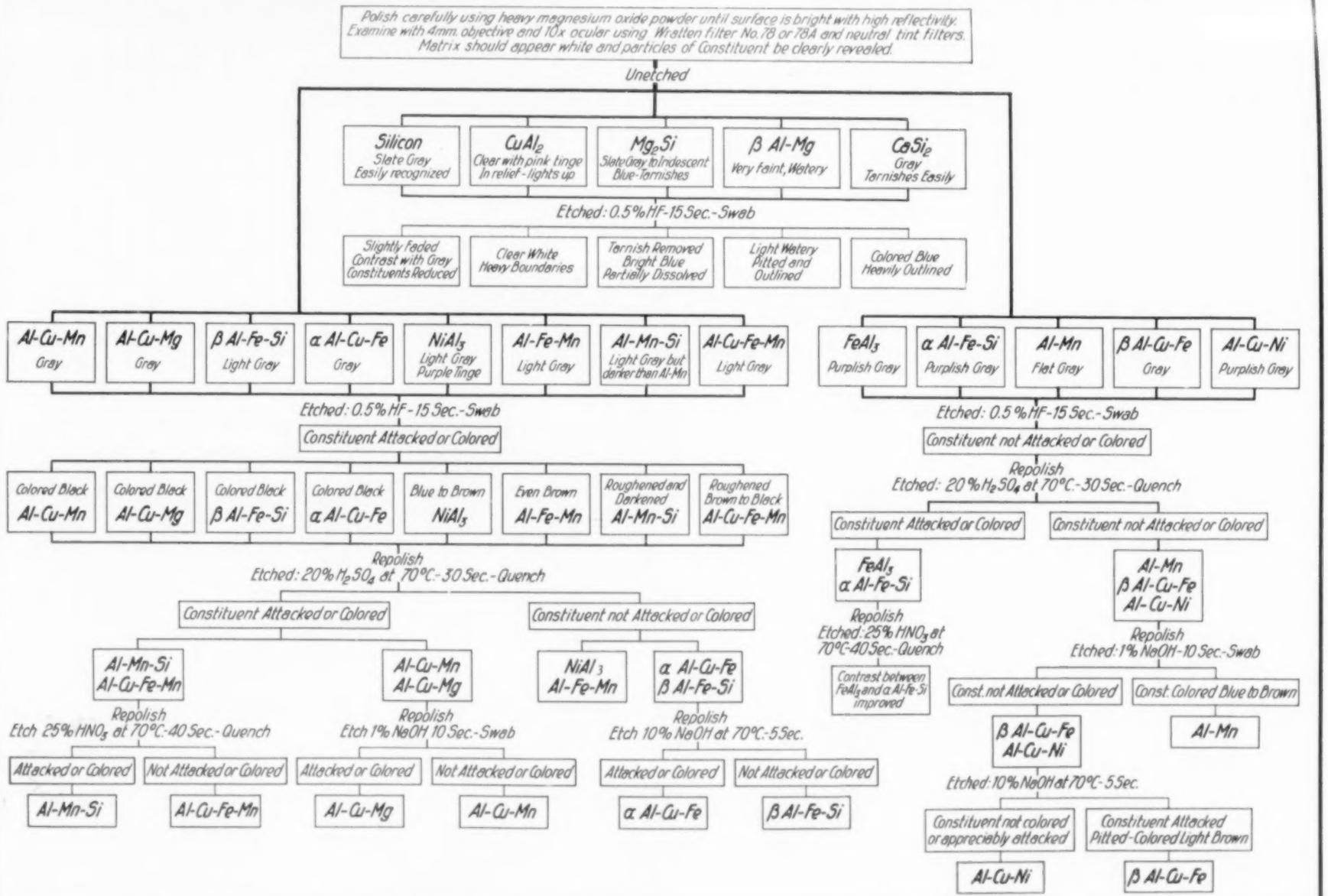
The 2% magnesium alloy (214) is notable for its corrosion resistance, and the 10%

Escalator in Chicago Department Store, "Streamlined" With Aluminum Sheet and Extruded Shapes, Gives an Elegant Effect and Permanent Beauty



Identification of Constituents in Commercial Aluminum Alloys

By F. Keller and G. W. Wilcox, Aluminum Research Laboratories (After Dix and Keith, with additions)



magnesium alloy (220), although difficult to handle in the foundry, can give an unsurpassed combination of strength, toughness, resistance to corrosion, and lightness. It is supplanting the 4% copper alloy (195) in heat treated castings for applications requiring the maximum strength and shock resistance.

Attention has been devoted in both Germany and Italy to the development of aluminum-base bearing metals and such alloys are reputedly in successful use, frequently replacing tin-base and copper-base alloys.

The use of aluminum as a minor alloying element in certain copper, nickel, iron and magnesium alloys is an expanding field. The reader is probably acquainted with the use of aluminum in condenser tube brass, aluminum in steel for nitriding, aluminum in resistor elements for high temperature service, aluminum in the grain size control and deoxidation of steel, and aluminum in the powerful nickel-cobalt magnets. More recently processes have been developed for continuously coating strip steel with aluminum, giving a product comparable to tinplate and of similar potential uses.

Pigging Light Alloy. Photograph by Margaret Bourke-White and courtesy Aluminum Co. of America

Magnesium Alloy Developments

Foreign magnesium production has been stimulated by the European political situation, but domestic production is growing normally. Fabricated magnesium products, including castings and wrought shapes, sold in the United States in 1936 approximated 1,000,000 lb., nearly double the corresponding figure for the year 1935. Several countries are now beginning the production of magnesium for the first time, and recently a process producing magnesium by thermal reduction and distillation from magnesite has been introduced commercially. Electrolysis of the fused chloride is still the more common process, however. Decided improvements in alloys and in technologic details have done much to account for the encouraging reception being accorded our lightest metal.

During the past few years there has been a marked change from the use of the conventional magnesium - aluminum - manganese alloys to somewhat similar alloys containing zinc and slightly lower in aluminum content. The newer alloys have better resistance to salt water corrosion and possess at least equal, and in many cases, superior physical properties. They respond to heat treatment, and a sand-cast alloy such as Dowmetal H with about 6% aluminum, 3% zinc, and 0.2% manganese will show 38,000 psi. tensile strength, 18,000 psi. yield strength, 5% elongation in 2 in., and 62 Brinell hardness when heat treated. These are noteworthy figures for an alloy approximately two-thirds the specific gravity of aluminum.

The British National Physical Laboratory reports some interesting experimental results on magnesium alloys containing, in addition to aluminum or cadmium, about 2% of silver and minor additions of manganese and calcium. Wrought alloys of this type have shown high yield strength and an ultimate tensile strength approaching 60,000 psi. An alloy of magnesium with cerium and cobalt has been developed that is stated to have high temperature properties comparable with those of the well-known Y alloy of aluminum. Further details appear in the article by C. H. Desch in METAL PROGRESS, March 1937.

Much progress has been made in melting and foundry practice, leading to the production

of metal with a higher order of resistance to corrosion. It is claimed in one process that an excess of manganese in the bath cleanses the metal of those harmful impurities such as iron; proper fluxes have likewise been developed that result in a similar improvement. Some work has been done in cladding the more corrodible, highly alloyed, wrought magnesium alloys with the corrosion resistant 2% manganese alloy. Great progress has also been made in surface treatments designed to improve the corrosion resistance and prepare the metal for protective coatings of paint, varnish, or enamel. A method has been recently developed at the National Bureau of Standards for the anodic oxidation of magnesium-base alloys which, while more costly than the widely used "chrome pickle," is said to be quite satisfactory and produces excellent results.

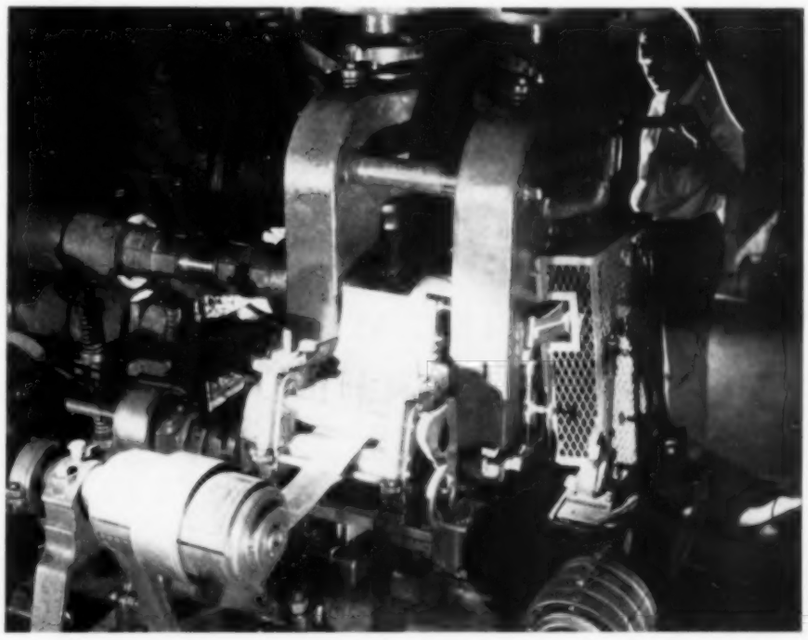
A better appreciation of certain fundamentals involved in forming operations has led to progress in the working and shaping of magnesium alloys. Although not capable of extensive working at room temperature, an additional slip plane becomes available in the crystals of magnesium at temperatures above 450° F., whereupon the metal "hot works" readily. Many commercial shapes are extruded.

The most outstanding new use for magnesium alloys is in die castings. Although previously used on a small scale for a number of parts, they are now in large scale commercial use. One of the better known American vacuum cleaners now contains five magnesium alloy die castings. The main casting, of irregular contour and thin section, is approximately 12 in. wide, 14 in. long, and 4½ in. deep. The manufacturer of this machine has recently completed a new plant wherein approximately 1000 sets of these die castings are produced per day. Satisfactory fluxes have also been developed to permit the manufacture of high pressure die castings of this type on a mass production basis.

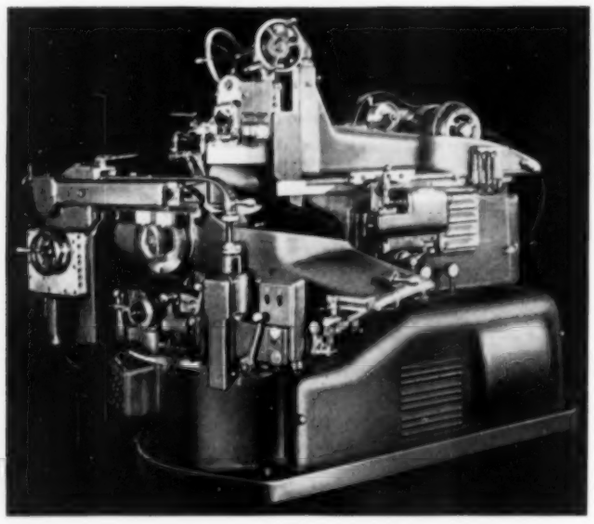
At the present time the majority of uses for magnesium alloys occur in the aviation industry, the portable tool industry, and in the machine industry where the extreme lightness of these alloys is a most advantageous feature for such applications.

Factors Making for Progress

In conclusion, the factors responsible for the remarkable progress in light alloys may be reviewed. Significant factors have been as follows: *(a)* Carefully planned, far-sighted research programs leading to technical progress in production of the metals from the raw materials available; *(b)* the development of entirely new alloys adapted to modern requirements; *(c)* the interest taken in aluminum and magnesium by large modern industries capable of utilizing considerable amounts of the metals; *(d)* the necessity for close technical control in the production and heat treatment of the alloys, placing the developments beyond the reach of personnel who are metallurgically stagnant-minded; and *(e)* an energetic, inspired program of consumer education. Each of these factors is still effectively operating and in consequence light alloy developments may be expected to proceed unabated in intensity and undiminished in scope.



Strong Magnesium Alloy Is Rolled Into Sheet and Strip of a Wide Variety of Thicknesses, Widths and Temper. Photograph courtesy Dow Chemical Co.



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Col. 1

Firestone

A story of the origin and history of Buckeye silica firestone makes an interesting preamble to a complete technical discussion of the properties and applications of this refractory. Cleveland Quarries Co. Bulletin Ka-176.

Ampco Metal

The six grades of Ampco metal, varying in hardness and physical properties but all possessing wear resistance, tensile strength and corrosion resistance, are described in a booklet which also lists its uses in modern industry. Bulletin Ka-175.

Chapmanizing

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Stainless Information

A table showing comparative characteristics and applications of 21 types of stainless steels made by Jessop Steel Co. is included in a comprehensive folder giving recommendations for forging and heat treating the various types. Bulletin Ka-173.

Stainless Specialties

The complete assortment of stainless steel specialties such as nuts, bolts, rivets, pipe fittings, etc. carried by Peter A. Frasse & Co. for prompt shipment to fabricators of stainless steels is catalogued with full information and prices. Bulletin Ka-172.

Disc Grinding

How disc grinding can be used as a production tool in the metal working industry is told in a 28-page booklet by Norton Company containing illustrations and explanations of a wide variety of applications. Bulletin Ka-88.

Refinery Specialties

Refinery tube supports and other specialties made of Ohio Steel Foundry Co.'s "Fahrite" heat and corrosion resisting alloys are the subject of a well-illustrated loose-leaf booklet. Bulletin Ka-40.

Col. 2

Drill Steels

An unusual and extremely valuable catalog on drill steels has been released by SKF Steels, Inc. Presented in a non-technical style, it is a practical book written for practical men. Bulletin Ka-18.

Wire Cloth

A looseleaf book of technical information on wire cloth and wire screen consists of tables of weights, diameters and prices, and a description of the various types of materials and weaves for different applications. Cambridge Wire Cloth Co. Bulletin Ka-178.

Insulating Cement

Complete information on a line of 14 types of high temperature and insulating cements known as "Sonitep" is contained in a handy file folder by George F. Pettinos, Inc. Bulletin Ka-179.

Oil Valves

The principle, performance, types and applications of Hauck micro regulating valves for exact, instant, and dependable control of oil at all times are given in an illustrated folder by Hauck Mfg. Co. Bulletin Ka-181.

Welding Stainless

A new 20-page booklet published by Republic Steel Corp. describes and illustrates the proper methods for welding stainless steel by electric arc, gas, seam, spot, projection, atomic hydrogen, and brazing and silver soldering. Bulletin Ka-8.

Improved Castings

The improvement of plain cast iron, nickel cast iron, nickel-chromium cast iron and nickel-chromium-molybdenum cast iron is technically presented in a 15-page article accompanied by tables, charts and illustrations. International Nickel Co. Bulletin Ka-45.

Heat Treat Chart

Heat treaters everywhere should find a heat treating wall chart complete with S.A.E. specifications a very valuable addition to their shops. Published by Chicago Flexible Shaft Co., manufacturers of Stewart industrial furnaces. Bulletin Ka-49.

Col. 3

Air Clutch Forging

Presented in considerable detail is information on Ajax bolt heading and forging machines, air clutch operated. Large photographs illustrate the 15 pages of text. Ajax Mfg. Co. Bulletin Ka-105.

Alnor Instruments

"Alnor" wall and portable pyrometers, thermometers, controllers, and air velocity meters for all sorts of general and specialized uses are fully catalogued by Illinois Testing Laboratories, Inc. Bulletin Ka-180.

High Tensile

The 19 advantages that USS Cor-Ten steel offers to railroads and other industries are attractively presented in a 68-page book on this new low cost, high tensile steel published by United States Steel Corp. Bulletin Ka-79.

Titanium Prices

A complete list of prices and terms on all of its products, which include many varieties of titanium and zirconium alloys, is published by Titanium Alloy Mfg. Co. Bulletin Ka-90.

Chromium

The rapidly expanding uses of chromium and its alloys in the chemical industry was the subject of an article by W. J. Priestley, vice-president, Electro Metallurgical Co., in a recent issue of "Industrial and Engineering Chemistry." Reprinted by Electro Met. as Bulletin Ka-16.

Liquitol

The use of Liquitol for controlled cooling of iron and steel castings and ingots is fully described in a bulletin by Alpha-Lux Co., Inc. Bulletin Ma-120.

Col. 4

Automotive Furnaces

Nowhere does heat treating play a more essential part than in the construction of the motor car. Gas-fired heat treating furnaces designed especially for use by the automotive industries are illustrated and described in a booklet by Surface Combustion Corp. Bulletin Ia-51.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Industrial Furnaces

Typical illustrations of a few of the thousands of Rockwell electric, gas and oil furnaces used in the metallurgical, ceramic and chemical industries are contained in an interesting bulletin by W. S. Rockwell Co. Bulletin Ka-34.

Hydraulic Tester

Of interest to all engineers recommending or purchasing universal testing machines is a book by Riehle Division of American Machine and Metals, Inc., on the development of the precision hydraulic testing machine. Bulletin Ba-157.

HELPFUL LITERATURE

Col. 5

Metals for Corrosion

Fourteen varieties of Midvaloy corrosion and heat resisting metals are described in a detailed bulletin by The Midvale Co. Properties and applications are listed and illustrated. Bulletin Ca-160.

Corrosive Solutions

A catalogue by Duriron Co. covers a complete line of equipment for handling corrosive solutions, with information as to sizes, capacities, dimensions and engineering data for innumerable items. Bulletin Ka-152.

Pure Metals

Pure, carbide-free metals are described and applications suggested in a pamphlet published by Metal & Thermit Corp., who make pure tungsten, chromium and manganese in addition to the ferro-alloys. Bulletin Ma-64.

Fine Steels

Compiled by men who make fine steels to assist men who use fine steels, a handy, pocket size, 150-page volume by Ludlum Steel Co. contains many new, helpful charts and tables, all made quickly available by a unique method of indexing. Bulletin Aa-94.

Oven Furnaces

In a nutshell American Gas Furnace Co.'s improved oven furnaces offer controlled atmosphere, quiet operation, economy, are over and under-fired and bottom vented. Described more fully in Bulletin Aa-11.

Easy Flow Brazing

Handy & Harman's Easy-Flo Brazing Alloy, a recent development, is recommended for joining stainless steel and iron, Monel metal, Inconel, Everdur and other ferrous and non-ferrous metals. Briefly described in Bulletin Ny-126.

Cleaning Rooms

A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-68.

Col. 6

Beryllium Copper

A reference work of new and up-to-date information on the unusual characteristics of beryllium copper contains helpful data on production, fabrication and heat treatment. Riverside Metal Co. Bulletin Fa-156.

Flame Hardening

The rapid development in recent years of the process of hardening with the oxy-acetylene flame well warrants the publication of this handsomely printed booklet which contains a multitude of excellent photographs of the applications of the process and of the equipment. Air Reduction Sales Co. Bulletin Ga-69.

Heat Treating Line

An attractive catalog of heat treating products is published by Park Chemical Co. It starts out with a very useful diagrammatic thermometer showing the temperature and ranges for the various heat treating, melting, and other processes requiring heat. Bulletin Oy-141.

The Laboratory

The latest issue of Fisher Scientific Co.'s interesting little magazine, "The Laboratory," containing articles of historical and practical value may be had by sending for Bulletin Ka-182.

Silico-Manganese

Bethlehem Steel Co. tells why silico-manganese steel is so well suited for heavy-duty springs of long life. Instructions for heat treating, physical properties and comparative fractures are included. Bulletin Ka-76.

Fatigue Test

A complete description of the fatigue test as made on the R. R. Moore fatigue testing machine is given in a folder by Baldwin-Southwark Corp. Examples are discussed and illustrated. Bulletin Ka-67.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Division of Carborundum Co. Bulletin Oy-25.

Col. 7

Rod Straightener

A brief but informative booklet on the American rod straightener and shear machine has been released by American Foundry Equipment Co. Features, operations and installations are thoroughly covered photographically. Bulletin Ka-112.

Union Service

Convincingly drawn up is a folder by Union Drawn Steel Co. stating the position held by the Company's representatives and the responsibilities placed upon them. Bulletin Ka-83.

Mo-W High Speed

J. V. Emmons, metallurgist for Cleveland Twist Drill Co. and largely responsible for the development of the molybdenum-tungsten high speed steels known as Mo-Max, has prepared a general description of these new steels. Bulletin Ka-103.

Conveyor Rolls

The record made by Calite alloy furnace conveyor rolls in a large steel mill having unusually heavy hearth loading is told in a leaflet by the Calorizing Co. Bulletin Ka-26.

Atmosphere Control

A device manufactured by Brown Instrument Co. and known as the "Analy-Graph" records minute changes in the chemical composition of a furnace atmosphere. How it works is told in Bulletin Ka-3.

Spoilage Fear

Fear of spoilage, says C. I. Hayes, Inc., may cost a firm more than actual tool loss through spoilage in the furnace. How "certain curtain" furnaces eliminate spoilage and spoilage fear is told in Bulletin Aa-15.

Hardening Furnaces

P. D. M. high speed hardening furnaces are described in two bulletins by The Philadelphia Drying Machine Co. — one devoted to oil-fired and one to gas-fired furnaces, both made in single and twin chamber models. Details of construction, design features and tables of sizes and capacities are included. Bulletin Oy-150.

Col. 8

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Brazing Carbides

Since the successful performance of sintered carbide tools depends on a solid, permanent braze, a description of the proper method and equipment for brazing carbide tools should form a handy folder. Firth-Sterling Steel Co. Bulletin Ka-177.

Wire Metallurgy

"The Metallurgy of Wire Manufacture" is the title of a paper presented before an A.S.M. Chapter by H. W. Graham, metallurgist, Jones & Laughlin Steel Corp. J. & L. has printed it for distribution in a booklet also containing Manufacturers' Standard Wire Specifications adopted by the Association of American Steel Manufacturers Technical Committees. Bulletin Ka-50.

Cinch Steel Cement

How Cinch steel cement saves high speed steel and Stellite by permitting the using up of short pieces is told in a bulletin by Claud S. Gordon Co. Bulletin Ka-53.

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-169.

Magnet Steels

A very handsome booklet describes the permanent magnet steels and castings made by Simonds Saw & Steel Co., including Alnico and Alnic. Bulletin Ba-158.

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

HEAT TREATING PROBLEM? YOUR ANSWER MAY BE HERE

HELPFUL LITERATURE

Col. 9

Optical Aids

Bausch & Lomb's new catalog lists and describes the instruments and accessories that are especially useful in the metal working industries, such as the toolmakers' microscope, the wide field binocular, the shop microscope, and the Brinell microscope. Bulletin Ga-35.

Molybdenum

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Galvanizing

An informative, historical, simple digest of galvanizing forms a guide to longer life for iron and steel products. This handsome, handy, 24-page book beautifully printed in color is distributed by American Hot Dip Galvanizers Association, Inc. Bulletin Ea-167.

Photoelectric Balance

C. J. Tagliabue Mfg. Co. has christened its newest, simplest and fastest recording potentiometer the "Celectray" from the photocell, electric current and light ray by means of which it operates. Described in Bulletin Ea-62.

Dipping Baskets

The fourteen standard designs of dipping baskets made by The C. O. Jelliff Mfg. Corp. are cataloged in a folder containing additional information on the types of metals most suitable for use with various cleaning and pickling cycles. Bulletin Sy-78.

New Homo Furnace

The new Homo furnace described in a bulletin issued by Leeds & Northrup provides for even tempering on a very dense load. Automatic control includes a feature that prevents overshooting. Fine tempering on extra dense loads at low cost is provided. Bulletin Mx-46.

Col. 10

Steel Data Sheets

Wheelock, Lovejoy & Co. gives analyses, physical properties, heat treating instructions, and applications of Hy-Ten, Economo, and S.A.E. alloy steels in concise and easily usable form. Bulletin Ox-74.

Brinell Tester

Accurate and exact measurements can be made on hard or soft materials with the Diamo-Brinell hardness testing machine, which uses a pyramid-shaped diamond instead of a steel ball. Described in a pamphlet by Pittsburgh Instrument and Machine Co. Bulletin Aa-1.

Casting Problems

Unusual casting problems that were solved by the use of National Alloy Steel Co.'s oxidation, corrosion, and abrasion resisting castings are shown in a clever pictorial manner in an attractive folder. Bulletin Ox-104.

Instrument Slide Rule

An ingenious slide-rule indicator devised by Westinghouse Electric & Mfg. Co. selects the proper instruments for any application, whether central stations, industrial plants or transportation industry. It shows at a glance what instruments to use, their range, approximate price, size, and descriptive literature available. Bulletin Ia-134.

Forging Machines

The Acme Machinery Co. has published an interesting bulletin on a distinctly new forging machine — the Model 35 Acme. This booklet illustrates and fully describes the new Acme Eccentric Heater Slide which eliminates entirely the conventional Pitman construction. Bulletin Ox-39.

Stainless Service

Joseph T. Ryerson & Son, Inc. has ten plants handling Allegheny stainless steel and service. A beautiful booklet describing and illustrating in color the products and services available is ready for distribution. Bulletin Jy-106.

Col. 11

Heat Treat Furnace

Particularly adapted to general heat treating operations in the tool room up to 1900° F. is the Model B-31 furnace described by American Electric Furnace Co. Bulletin Ka-2.

Radiation Pyrometer

The Pyro radiation pyrometer for temperatures exceeding 1000° F. is a light-weight, handy, and simple automatic instrument made by Pyrometer Instrument Co. Its features, methods of use, and applications are given in Bulletin Ax-37.

Stainless Slide Chart

Carpenter Steel Co.'s pocket-size slide chart gives at a glance the technical data on all stainless steels. Bulletin Jy-12.

Steel Service

"Steel Service" is the title of a bulletin which gives valuable information on testing methods and pickling control charts. It is distributed by the Grasselli Chemicals Department of E. I. du Pont de Nemours & Co. Bulletin Aa-95.

X-Ray Examination

The application of X-ray examination and inspection of castings, welding, and food products, as well as practical X-ray crystal analysis, is completely described and strikingly illustrated in General Electric X-Ray Corp.'s new 34-page publication. Bulletin Dy-6.

Melting Furnaces

Pittsburgh Lectromelt Furnace Corp. offers a folder describing its line of new top-charging melting and refining furnaces. Economies of top-charging are analyzed and much information on operation and construction is given. Capacities range from 50 lb. to 50 tons. Bulletin Jr-18.

Aerocase

A modern method for casehardening and heat treating steel in a liquid bath is provided by the use of Aerocase compounds, which have been in commercial use for more than six years. Their principal features are described by American Cyanamid and Chemical Corp. in an interesting booklet. Bulletin Oy-148.

Col. 12

Tocco Process

This amazing new and extremely accurate method of heat treating is described in a new four-page leaflet, yours for the asking. Distributed by Ohio Crankshaft Co., Bulletin Oy-145.

Boxes and Trays

Standard Alloy Co. offers all those advantages which spring from long specialization in heat and corrosion resisting alloy castings for such things as boxes and trays. An abundance of proven data is contained in Bulletin Oy-151.

Port Valves

Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

Prevention of Rust

"Proof of Results" is the apt title of a new booklet issued by Dearborn Chemical Co. Dozens of photographs, supported by an interesting text, show how No-Ox-Id keeps steel from rusting. Bulletin Mr-36.

Vanadium Facts

Revived after nearly 20 years is the house organ of Vanadium Corp. of America, "Vanadium Facts." This paper shows considerable thought and care in its preparation and contains valuable and interesting information on vanadium steels. Bulletin Ox-27.

Aluminum News

A cleverly written, well-illustrated newspaper of interesting items about aluminum is issued by Aluminum Co. of America every month. The latest issue is Bulletin Jy-54.

Model "Y"

The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

USE THE CONVENIENT COUPON — PAGE 593

HELPFUL LITERATURE

Col. 13

Cement

"Hytempite" is a high temperature cement for laying up firebrick with thin, long-lasting, air and gas tight joints of great strength, made by Quigley Co. How it saves time and labor and cuts construction and maintenance costs is told in Bulletin Ia-139.

Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

Arc Welding Future

Harnischfeger Corp. takes a look at the future of arc welding in a booklet stressing the simplicity of "Smootharc" welders. Illustrated with a wealth of photographs, drawings and cross-sections. Bulletin Ha-171.

Scleroscopes

Shore Instrument & Mfg. Co. describes its Model D standard recording scleroscope in a recent bulletin which explains the theory and practice of hardness testing with this machine. Bulletin S-33.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data are given in Bulletin Fx-57.

Salt Bath

"Heating from the inside out" is what makes the Ajax-Hultgren salt bath furnace practical. Ajax Electric Co. explains this new operating principle in an interesting folder. Bulletin Oy-43.

Alloy Steels

Why alloy steels are best for heavy equipment and other exacting applications is discussed in a folder by Bliss & Laughlin, Inc. A partial list of the more common grades gives machine ratings and turning speeds. Bulletin Jy-42.

Col. 14

Air Weight Control

An illustrated booklet of sure-fire interest to the foundry trade has been issued by The Foxboro Co., explaining in detail the advantages of the "air weight controller" which is in use at many of America's leading foundries, named in the publication. Bulletin Ea-21.

Furnace Parts

A valuable feature of Driver-Harris Co.'s folder on Nichrome cast furnace parts is a table giving the tensile strength of Nichrome castings at various temperatures. Bulletin Da-19.

Chromel

A new catalog has been issued by Hoskins Mfg. Co. covering Hoskins electric furnaces and Chromel elements, which provide uniform heat and automatic temperature control with excellent production and quality of work. Bulletin Ia-24.

Tempering

Vertical batch type tempering furnaces are described in a folder by Industrial Heating Equipment Co. Capacity and production figures and a diagram of the furnace are included along with a complete description. Bulletin Ia-168.

Pipe Lines

Latest information on the construction of pipe lines by electric welding for transportation of oil, gas and water is contained in a bulletin by Lincoln Electric Co. Fourteen pages, profusely illustrated. Bulletin Ia-10.

Scale-Free Hardening

General Electric scale-free hardening furnaces for either large or small volume of production, ferrous or nonferrous applications, box or continuous type, are accurate and automatic. Described in Bulletin Ia-60.

Explosion Protection

A gas burner safety device designed to prevent explosion made by Wheelco Instruments Co. is known as the Flame-otrol. Illustrations, data, operating diagrams and prices are fully covered in Bulletin Ia-110.

Col. 15

Testing Machines

An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Oxidation

Designers confronted with oxidation problems connected with cracking coils, polymerization plants, superheaters, high pressure steam plants, air heating equipment and recuperators will welcome a folder by Timken Roller Bearing Co. containing data on oxidation at 1000, 1250 and 1500° F. Bulletin Ea-71.

Pickling

All current pickling procedures and practices were carefully studied, analyzed, summed up and compared in the preparation of a 32-page handbook on pickling steel with modern inhibitors by E. F. Houghton & Co. A frank, instructive manual. Bulletin Ia-38.

Pyromaster

Bristol Co.'s "Pyromaster" is a recording potentiometer with a round chart and direct ink marking. Its applications as a pyrometer, resistance thermometer, tachometer and millivoltmeter are given in Bulletin Ia-87.

Rustproofed Steel

Atmosphere does not corrode steel which has been rustproofed with Duozinc, a mercury-containing zinc anode with marked production properties. Full details are given in a folder issued by the R. & H. Chemicals Dept. of duPont. Bulletin Ar-29.

Cutting Oils

The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jy-118.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Col. 16

Compressor Data

General information on the application of blowers to gas and oil burners, and miscellaneous applications for other types of work are included in a 12-page "Turbo-Compressor Data Book." Useful tables and charts are included. Spencer Turbine Co. Bulletin Dy-70.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

Hy-Speed Case

50 to 500% increase in the life of high speed steel tools is claimed in a striking and interesting new booklet just published by the A. F. Holden Co. Typical cases of these savings are cited. Bulletin Fa-55.

Metallograph

Leitz Large Micro-Metallograph "MM-1" — most interesting 36-page publication containing numerous photomicrographs on the very latest developments in metallographic equipment. Special attention is given to darkfield illumination. Bulletin Ha-47.

New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive non-oxidizing furnace atmosphere and their new, continuous brazing, coppering and soldering furnaces. Full details are given in Bulletin Ar-30.

Centrifugal Iron

A bulletin descriptive of the recent development and production of centrifugally cast alloy irons, Ni-Resist, and other compositions by Shenango-Penn Mold Co. includes the chemical analysis, physical properties and uses of four standard gray iron compositions. Bulletin Ka-174.

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HELPFUL LITERATURE

Col. 17

Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Dust Collector

How the Schneible multi-wash dust and fume collector operates and what it does are clearly shown in a catalog giving details on existing installations. Published by Claude B. Schneible Co. Bulletin Ca-161.

Meehanite

A compact but complete specification chart gives the recommended grades of Meehanite metal for various service requirements. Complete physical properties and applications are included. Bulletin Da-165.

Firebrick

Babcock & Wilcox make an insulating firebrick which is refractory as well as insulating and can be used without a facing of firebrick. Description, applications, and engineering data are contained in Bulletin Fy-75.

Col. 18

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

Electric Salt Baths

Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Copper Bulletin

A new clearing house for news of developments in brass, bronze, and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

Col. 19

Cold Finished Facts

Leather-bound, looseleaf, and tabbed for easy reference, a handbook by Wyckoff Drawn Steel Co. on cold finished steels abounds in useful technical information on machinability, heat treatment, selection of steels, and weight tables. Bulletin Ka-99.

Baking Ovens

For refrigerators, air conditioning units, oil burners, bed springs, switch boxes, motor parts, steel furniture, stove and furnace parts, the various types of finish baking and drying ovens made by Despatch Oven Co. are described in Bulletin Ka-123.

Laboratory Service

A new edition of "The Metal Analyst" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Col. 20

Polishing Machine

A reprint of an article from the A.S.M. Transactions by O. E. Romig and J. C. Whetzel is supplemented by photographs, specifications, and other information on the Cincinnati Electrical Tool Co.'s new metallographic polishing machine. Bulletin Ox-97.

Uniform Temperature

Temperature Uniformity is the title of an interesting bulletin describing Carl-Mayer furnaces for tempering, drawing, aging and heat treating. With temperature uniformity so important to efficient furnace operation, every heat treater will want this literature. Write for Bulletin Ka-183.

Cutting Steel

Recommended practices for gas cutting of structural steel are given in a concise and authoritative form by The Linde Air Products Co. Qualification tests for good workmanship from the standpoint of accuracy and smoothness of cuts are also described. Bulletin Dc-63.

Thermal Analyzer

Laboratory furnace equipment designed to conduct grain size tests, creep tests, thermocouple calibration, coefficients of expansion, combustion analysis, gas atmosphere experiments, dilatometry, and general thermal exploration. Also for precision heat treatment. Stanley P. Rockwell Co. Bulletin Ay-121.

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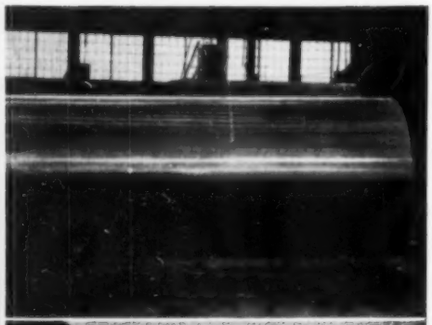
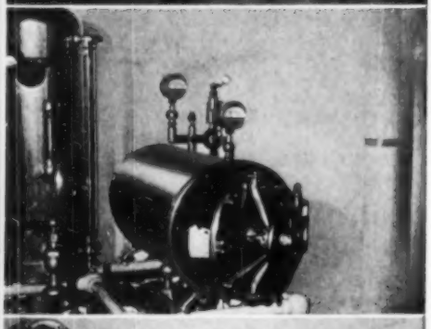
Ka-60	Ka-49		Ba-157						Oy-148	Oy-114	Jy-42	Ia-110	D-17	Ka-174					

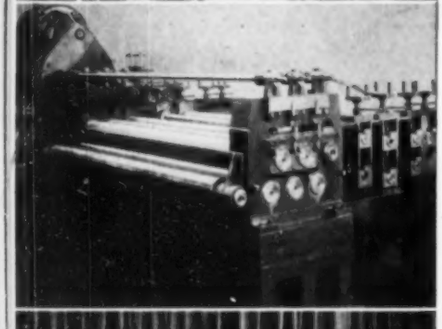
JESSOP

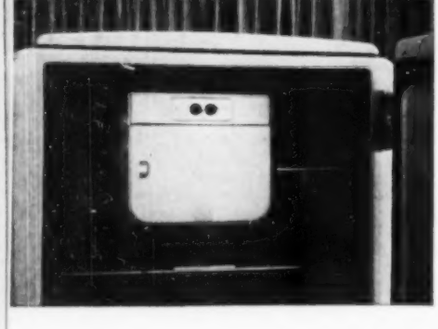
STAINLESS STEELS

FOR EVERY PURPOSE









Stainless Steels must be "tailor made" to fit each job.

Stainless Steels are reaching an ever-broadening market. They are being used for appearance, to resist atmospheric corrosion, to withstand the "bite" of chemicals, to face high temperatures.

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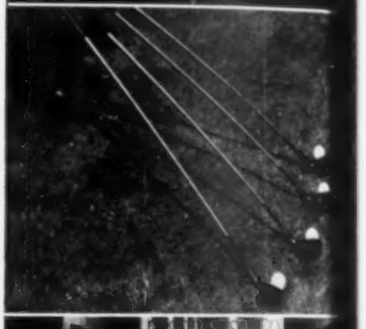

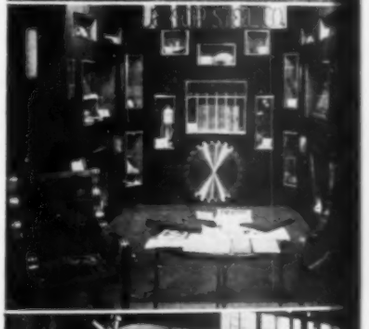

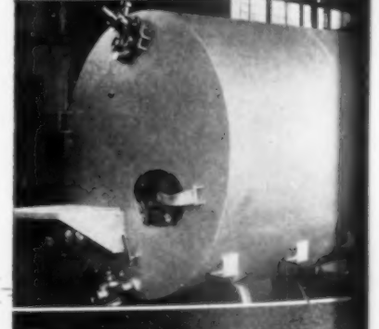

JESSOP STEEL COMPANY

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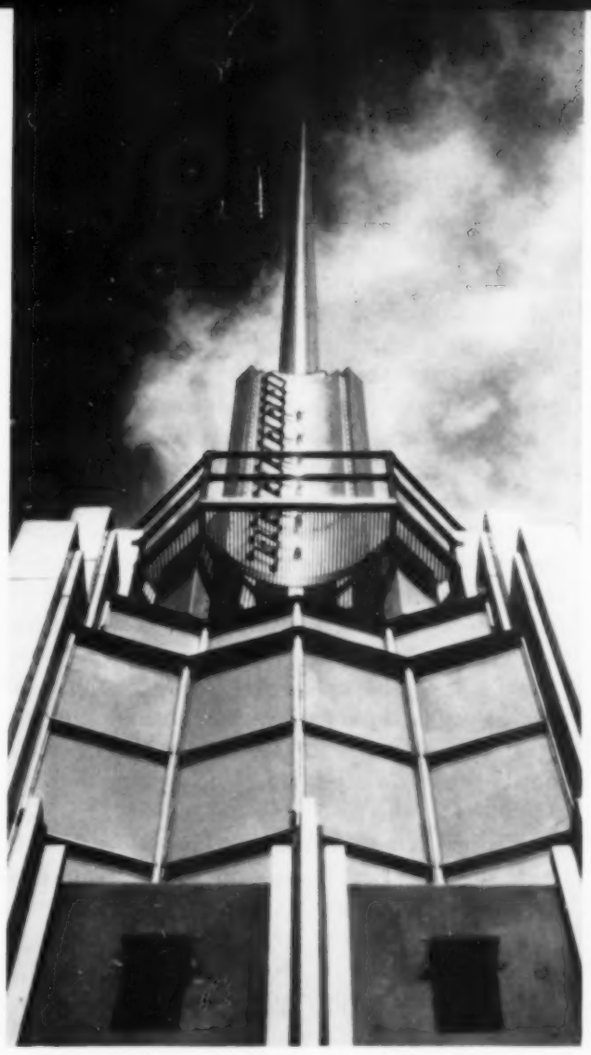
Diversification of Stainless for Special Purposes

By E. E. Thum*

Editor

Metal Progress



Stainless Steel Has Been Successfully Employed by Architects for Exterior Trim and Ornamentation for Monumental Buildings as Well as Small Store Fronts

A REVIEW of the wrought stainless steels — or, more precisely, the high chromium-iron and chromium-iron-nickel alloys — would largely concern itself with listing a multitude of expanding applications, and would be rather dull reading. These alloys and their modifications have such remarkable properties that everyone who must use metal at high temperature, or expose it to unduly corrosive surroundings, or even in services where a light tarnish is objectionable, naturally turns to one or another of them. It is truly remarkable that such a large majority of these applications, often tried more or less blindly, are as successful as they are. As to the remainder, it is only natural that the severest demands are not perfectly met — nothing is a cure-all. We find, therefore, that recent progress in the stainless steels has not been in the development of new alloys, but the slight modification of those we already have to make them better adapted to this, that, or the other highly specialized use.

Take for instance the chromium steels used extensively in the oil industry. Seamless tubing of 18% chromium, 8% nickel was early used in the high temperature cracking stills for producing the maximum amount of gasoline from petroleum. These chemical processes changed so fast, however, that a cracking still would become obsolescent long before any appreciable damage had been done to the high alloy tubing. Since 18-8 is quite expensive, the demand was for another steel, intermediate in high temperature corrosion resistance between it and plain carbon boiler tubes, a demand met by a plain chromium steel carrying from 4 to 6% of the alloying element. (Even lower chromium alloys have been more recently introduced, utilizing

*Valued assistance was received from Russell Franks and other members of the technical staff, Union Carbide & Carbon Corp., in preparing this article.

considerable silicon to increase the oxidation resistance, and some molybdenum to improve the high temperature strength.)

Some peculiar troubles developed in the plain 4 to 6% chromium still tubes after months at 800 to 1100° F. These tubes are quite ductile at service temperatures, but during winter shutdowns some of them broke while being cleaned, thus indicating that they had become embrittled (as far as atmospheric temperature was concerned) by some obscure change. Since this type of fracture did not occur in those tubes to which some molybdenum had been added to increase the creep strength, it was supposed that molybdenum was the cure — although more recent experiments indicate that the impact strength of such steels with molybdenum is only moderately better than that of those containing no molybdenum after long anneals at 1000° F.

Embrittlement after long heating is thought to be due to some change in solubility of carbide in the iron matrix of this alloy, and hence is associated with the strong air hardening propensities of the low and medium chromium steels, as well as the phenomenon of temper brittleness (embrittlement after slow cooling from a tempering or annealing heat). Air hardening can be prevented by adding enough of a strong carbide-forming element, such as titanium, to lock up the carbon in insoluble carbides which to all intents and purposes are non-metallic inclusions. It was thought that if the carbon was locked up tightly enough, the three deficiencies could be cured at one and the same time — namely, air hardening, temper brittleness, and embrittlement after long heating.

While titanium is quite successful in preventing air hardening, and molybdenum in preventing temper brittleness, it is shown by Russell Franks in a paper for the forthcoming ⊕ Convention that columbium carbide has such a high degree of insolubility in ferrite and austenite that even minute amounts of it do not go in and out of solution after long stays at high and room temperature, respectively. It results, therefore, that the 4 to 6% chromium steels, with six to ten times as much columbium in them as there is carbon, will retain their original toughness (Izod impact about 100 ft-lb.) after a very long stay at any temperature up to 1400° F., when these steels are tested either at room temperature or after chilling to —40° F.

Approximately 1000° F. is the upper working limit for the 4 to 6% chromium steels, and 1600° F. for 18-8. An intermediate alloy containing about 9% chromium and 1.5% molybdenum has been found quite suitable for service up to about 1250° F. Its creep strength is satisfactory, and when carbon is below 0.15% it is structurally safe after long-time heating, and free from embrittlement on cooling.

Toughening the Chromium Irons

The foregoing remarks on carbon have to do with the chromium *steels*. We attempt to neutralize its action and produce non-hardenable chromium *irons*. This we already have when we raise the chromium high enough — beyond 17 or 18%, even to 25%. These alloys are unrivaled for resistance to high temperature scaling, yet their great defect is that they cannot be grain refined by heat treatment.

Coarse ingot crystals make them delicate to handle during hot work, and the alloys when cold have a large grain size and relatively low impact resistance. Such alloys are ferritic (alpha iron) at all temperatures; lacking any transformation point or change in carbide solubility, it is impossible to recrystallize them by heat treatment; in fact, the more they are heated, the larger the grains are apt to grow. To alleviate this condition it was necessary to discover something which would go into and out of solution in the alpha crystals with rise and fall of temperature, and fortunately nitrogen (introduced in the form of high nitrogen ferrochromium) does just that. Nitrogen in the alloy has permitted the production of 25% chromium-iron sheets, plates and tubes which have been very widely used in chemical processes and other high temperature services. These alloys resist oxidizing atmospheres almost up to the melting point.

Nitrogen in the form of chromium nitride increases the strength of the 13 or 14% chromium steels (rolled in large tonnage into strip for the automotive industry) without lowering ductility and toughness, neither is there any loss in corrosion resistance — as is the case when carbon content is increased.

In England the 18% chromium steel, which normally is ferritic and non-hardenable, is changed into a martensitic, hardenable steel by the addition of about 2% nickel. This is quite a popular alloy over there and is especially interesting for an increased resistance to corrosion by sea water.

Reports from Germany indicate a strong

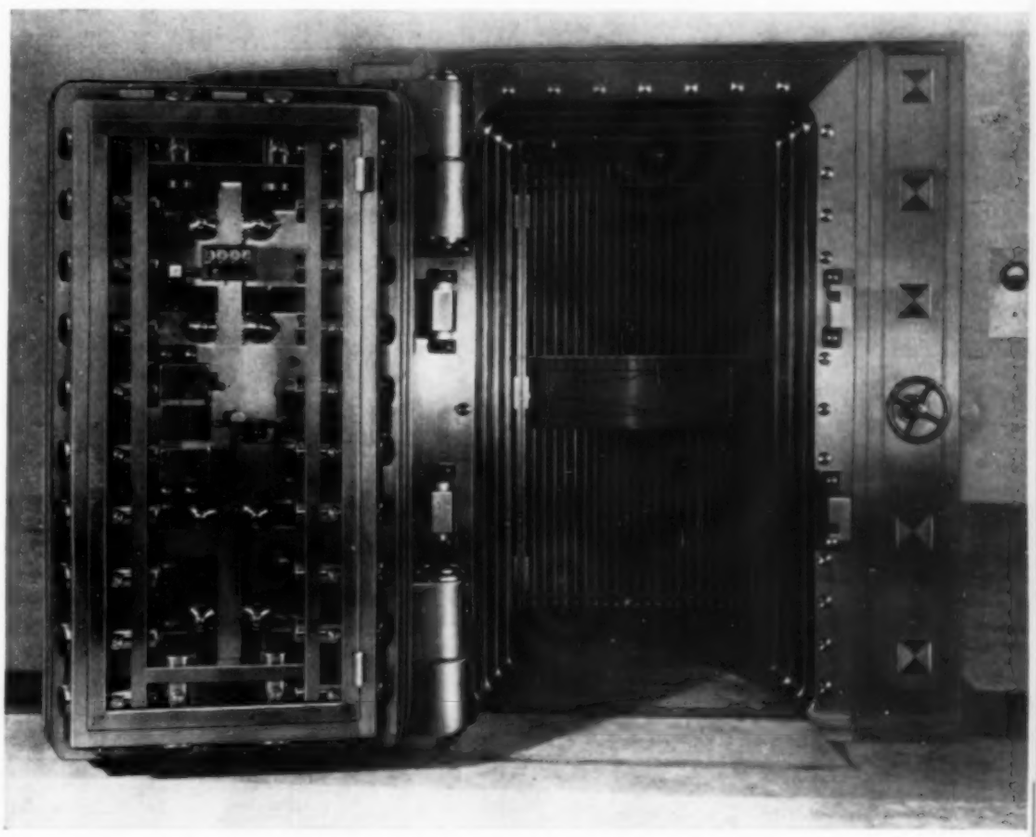
commercial urge toward the straight chromium steels rather than the chromium-nickel steels not only to avoid a restrictive patent situation on the popular 18-8 variety, but to surmount import restrictions on nickel. Hence the 18% chromium with molybdenum is going into nitric acid equipment and the straight chromium steels with aluminum or silicon into heat resistant parts. In France a low carbon 18% chromium alloy has been extensively worked into flatware and domestic utensils.

High Chromium-Nickel Alloys

Chromium, sometimes fortified with aluminum and silicon, is the best alloy for lending chemical stability to iron — that is, improving resistance to oxidation, sulphidation, and most other chemical attacks. Nickel in generous proportions has been added to improve the toughness, refine the grain, and impart good creep resistance (high temperature strength).

Of course, the all-purpose alloy is the one popularly known as 18-8. In the wrought form it contains up to 0.20% carbon, but for many purposes this is driven down to 0.08 or even 0.07%. The higher carbons are somewhat easier to make and fabricate and are amply good for exposure to mild corrosion. Strength also increases with the carbon. While the plain 18-8 variety is very widely used, a number of modifications have been made by adding this that or the other element for specific uses.

One of the first serious troubles with 18-8 had to do with rapid corrosion at and alongside of welded joints. This set back the utilization of the alloys somewhat, but probably not as seriously as some later troubles with sea water, because the welding troubles were quickly discovered and diagnosed by metallurgists, and preventives adopted. One prominent manufacturer in England avoids this "weld decay" by alloying up to 6% of silicon with the 18-8. Since the trouble is due to the precipitation of chromium-rich carbides at the austenitic grain boundaries during moderate reheatings in the range between 800 and 1500° F., German practice (as well as American) is more toward driving the carbon down to 0.07% or less, and fixing that which is left with some strong carbide forming element such as titanium, tantalum or columbium. "Stabilization" by a combination of cold work and annealing at 1400° F. to precipitate the carbides and re-diffuse the chromium is also successful. Others believe that the conventional types of 18-8 may be welded with impunity if the welded parts are of such form and shape that they can be heated to about 2000° F. to put the precipitated carbide back into solution and then the metal rapidly cooled to keep it there. Of course, an 18-8 alloy with moderate carbon content (especially with chromium and nickel on the high side) may be welded and placed into many kinds of service resisting mild corrosion. *(Turn to page 602)*



A Duplex Metal — Hard Chromium Steel on the Outside to Resist a Hack Saw and Tough Wrought Iron on the Inside to Resist a Sledge — Was the Old Standard for Vault and Safe Construction. The new high chromium steel is now favored for trim because of its reasonable cost, ease of fabrication and resistance to stain

Properties of the Principal Cr-Fe Alloys

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Chemical composition							
Chromium	1.75 to 2.25	4 to 6	8 to 10	12 to 14	13 to 14	16 to 18	25 to 30
Nickel	(0.5 Mo)	—	(1.5 Mo)	—	—	—	—
Si and Mn (max.)	0.50	0.50	0.50	0.50	0.55	0.50	0.50
Carbon	0.15 max.	0.10 to 0.20	0.15 max.	0.10 max.	0.30 to 0.40	0.10±	0.10±
Specific gravity							
Lb. per cu. in.	—	0.280	0.282	0.276	0.278	0.273	0.270
(Mild steel = 1.00)	—	0.99	1.00	0.97	0.98	0.96	0.95
Electrical resistance							
Microhms per cm^3	—	—	—	57	60	59	67
(Mild steel = 1.00)	—	—	—	5.2	5.5	5.4	6.1
Melting range, °F.							
Top	—	2800	—	2790	2750	2750	2750
Bottom	—	2760	—	2750	2580	2710	2710
Structure	Pearlitic	Pearlitic	Martensitic	Martensitic	Martensitic	Ferritic	Ferritic
Magnetism							
Ferromagnetic	Yes	Yes	—	Yes	Yes	Yes	Yes
Permeability: As annealed	—	—	—	—	—	—	—
Permeability: Cold worked 10%	—	—	—	—	—	—	—
Specific heat							
C.g.s. units, 0 to 100°C.	—	0.11	—	0.11	0.117	0.11	0.11
(Mild steel = 1.00)	—	1.0	—	1.0	1.1	1.0	1.0
Thermal conductivity							
*C.g.s. units at 100°C.	—	0.0874	—	0.0595	0.05	0.0583	0.0500
(Mild steel = 1.00)	—	0.73	—	0.50	0.42	0.49	0.42
C.g.s. units at 500°C.	—	0.0803	—	0.0686	—	0.0624	0.0583
Thermal expansion per °F. x 1,000,000							
From 32 to 212°F.	—	6.1	6.29	6.1	5.7	6.0	5.9
(Mild steel = 1.00)	—	0.93	0.95	0.93	0.87	0.91	0.90
From 32 to 932°F.	—	7.2	7.00	6.7	6.6	6.7	6.3

Mechanical Properties at Room Temperature	An-nealed	An-nealed	†Heat Treated	An-nealed	An-nealed	†Heat Treated	An-nealed	††Heat Treated	An-nealed	Cold Worked (Wire)	An-nealed	Cold Worked (Wire)
Ultimate strength, 1000 psi.	60 to 70	66	115	75 to 87	65	125	100	230 to 260	75	100 to 190	75 to 95	85 to 175
Yield point, 1000 psi.	30 to 45	27	103	35 to 45	35	100	65	200 to 220	40	—	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	—	—	—	—	28	—	—	—	29	—	—	—
Elongation, % in 2 in.	40 to 30	38	20	40 to 30	35	20	27	8 to 2	27	—	30 to 20	—
in 10 in.	—	—	—	—	—	—	—	—	—	25 to 2	—	25 to 2
Reduction of area, %	—	76	66	—	65	60	59	20 to 2	55	40 to 20	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	—	—	35 to 60	—	75	—	—	—	—	—	—
Izod	—	80	75	—	80	—	—	—	8 to 25	—	—	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	—	—	—	—	—	—	—	—
Hardness, Brinell	130 to 160	136	250	145 to 180	140	230	170	480	175	185 to 270	160 to 190	150 to 250
Rockwell	—	B-75	C-24	—	B-76	C-22	—	C-56	B-85	B-90 to 105	B-80 to 90	C-0 to 25
Erichsen value, mm.	—	—	—	—	—	—	—	—	7 to 9	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	11,400	7,000		11,600	13,000				8,500		—	
at 1100	5,650	—		6,950	—				—		—	
at 1200	3,150	—		2,300	2,300				2,100		1,600	
at 1350	—	—		—	1,400				1,200		400	
Scaling temp., °F.		1200		1200	1300		1750		1550		2100	
Initial forging temp., °F.		2100		—	2100		2000		2000		2200	
Finishing temp., °F.		About 1400		—	max. 1450		1700		max. 1400		max. 1400 to 1450	
Annealing treatment		Furnace cool from 1580°F.		—	Prolonged heating at 1250 to 1350°F.		1575 to 1625°F.		**		1 hr. or more at 1450°F. and quench	

* Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.
† Quenched and drawn at 1100°F. †† Oil Quenched from 1850°F. and drawn.
** Small cold reduction, followed by anneal at 1400°F. and quench

Properties of the Principal Cr-Ni-Fe Alloys

	18-8			18-12		25-12		25-20	18-26
Chemical composition									
Chromium	17 to 19	Modifi-		17 to 19		22 to 28		24 to 26	17.5 to 19.5
Nickel	8 to 10	cation		11 to 12.5		12 to 16		19 to 21	25 to 26
Si and Mn (max.)	0.50	with		0.50		—		1.0 & 0.75	3.0 Si max.
Carbon	0.10	titanium		0.10		0.15±		0.15 max.	0.20 max.
Specific gravity									
Lb. per cu. in.	0.286	0.285		0.287		0.283		0.285	0.280
(Mild steel = 1.00)	1.01	1.01		1.02		1.0		1.01	0.99
Electrical resistance									
Microhms per cm.³	70*	71		73		78		90±	102
(Mild steel = 1.00)	6.4	6.5		6.7		7.1		—	9.3
Melting range, °F.									
Top	2590	2590		—		2570		2600	—
Bottom	2550	2550		—		2530		2550	—
Structure	Austenitic	Austenitic		Austenitic		Austenitic		Austenitic	
Magnetism									
Ferromagnetic	—	—		—		—		Trace	—
Permeability: As annealed	1.003	1.003		1.003		1.003		1.003	—
Permeability: Cold worked 10%	1.10	—		1.006		1.003		—	—
Specific heat									
C.g.s. units, 0 to 100°C.	0.12	0.12		0.12		0.12		—	—
(Mild steel = 1.00)	1.1	1.1		1.1		1.1		—	—
Thermal conductivity									
** C.g.s. units at 100°C.	0.0390	0.0385		0.0380		0.03 to 0.04		0.03 to 0.04	—
(Mild steel = 1.00)	0.33	0.32		0.32		—		—	—
C.g.s. units at 500°C.	0.0515	0.0528		0.0520		—		—	—
Thermal expansion per °F. x 1,000,000									
From 32 to 212°F.	9.6	9.3		9.9		8.3		8.8	8.8
(Mild steel = 1.00)	1.45	1.40		1.50		1.26		1.33	1.33
From 32 to 932°F.	10.2	10.3		10.8		9.6		9.4	9.3
Mechanical Properties at Room Temperature	Annealed	Cold Worked (Wire)	† Stabilized	Annealed	Cold Worked (Wire)	Annealed	Cold Worked (Wire)	Annealed	Annealed
Ultimate strength, 1000 psi.	80 to 90	105 to 300	85 to 95	80 to 90	105 to 275	90 to 110	110 to 270	80 to 110	90 to 110
Yield point, 1000 psi.	40	60 to 250	40 to 45	40	—	40 to 60	65 to 230	35 to 65	45 to 50
Elastic modulus, 10^6 psi.	29	—	—	—	—	—	—	—	30±
Elongation, % in 2 in.	60	—	55	60	—	50 to 35	—	60 to 45	35 to 30
in 10 in.	—	50 to 2	—	—	50 to 2	—	35 to 2	—	—
Reduction of area, %	70	65 to 30	55	65	65 to 30	60 to 45	55 to 20	—	45 to 35
Impact, ft-lb.; Charpy	—	—	72	—	—	—	—	40 to 80	—
Izod	75 to 110	—	—	—	—	—	—	—	50 to 90
Fatigue endurance limit, 1000 psi.	47	50% of ultimate		—	—	—	—	—	—
Hardness, Brinell	135 to 165	170 to 460	150 to 185	135 to 165	170 to 380	150 to 185	170 to 375	130 to 190	160 to 185
Rockwell	B-75 to 85	C-5 to 47	B-80 to 90	B-75 to 85	C-5 to 40	B-80 to 90	C-5 to 40	—	—
Erichsen value, mm.	11 to 14	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	12,000							—	7,000
1200	7,000							7,400	—
1350	3,000							3,300	—
1500	850							1,100	—
1600	—							—	1,900
Scaling temp., °F.	1650		1650	1650		2100		2000	1650
Initial forging temp., °F.	2200		—	As for 18-8		2200 to 2300		—	1950
Finishing temp., °F.	Not under 1600 to 1700		—	As for 18-8		Not under 1600 to 1700		—	—
Annealing treatment	Heat at 1900 to 2000°F. and quench		††	As for 18-8		Heat at 2000 to 2150°F. and quench		—	As for 18-8

* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm. cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

† Small cold reduction, followed by anneal at 1400°F. and quench

†† Final heat treatment must consist of 2 to 4 hr. soak at 1550°F.

Where wet corrosion is not a factor, nor the moderate embrittlement induced in 18-8 by a stay at these intermediate temperatures, 18-8 has proven excellent in service up to 1500 or 1600° F. The metal does not remain stainless at that temperature — in fact, it acquires a brown tarnish at a low temperature, 400° F., but this oxide coating is strongly adherent and impervious to further oxygen penetration.

Higher Alloy Combinations

Two other alloys of higher chromium and nickel have been introduced and are much more suitable for high temperature service. The so-called 24-12 (which may carry from 22 to 26% chromium and 10 to 14% nickel) resists oxidizing and corroding atmospheres up to 1850° F. For somewhat higher temperatures, and more especially where high pressures must be resisted by a metal with good creep resistance, an alloy with approximately equal portions of both chromium and nickel (20 to 25% chromium and 20 to 22% nickel) is preferred. Both of these have their optimum physical properties after annealing and rapid cooling from about 2000° F., and as can be seen by the attached diagram, the ultimate strength is on the order of 100,000 psi., reduction of area about 60%, Brinell hardness as low as 150, and the Izod impact very high — over 100 ft-lb.

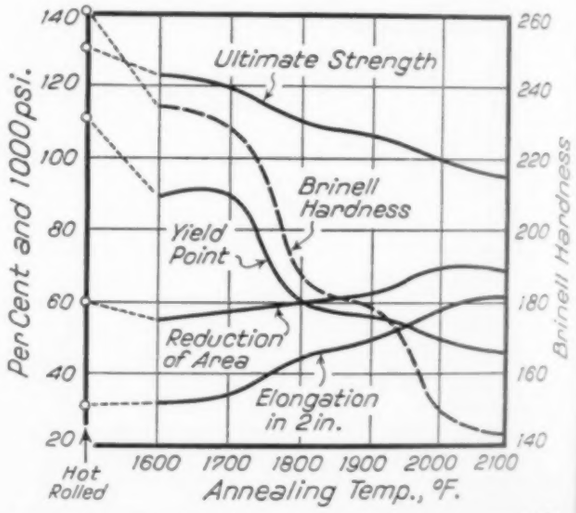
In either of these higher alloys carbon can be upped materially over that necessary in standard 18-8, and still retain a good austenitic structure. However, in order to retain good Izod impact, 0.15% carbon should be the maximum. Where maximum resistance to corrosion is required, this should still further be reduced to 0.07 or 0.08%.

Pitting by Sea Water

As before indicated, no one of these chromium or chromium-nickel alloys is a cure-all, and consequently when one of them fails in a certain service, it is no more than might be expected. For instance, one would be foolish to condemn 18-8 for not resisting active chloride solutions. What alloy does? 18-8 will resist hundreds of active corroding media that less noble alloys of iron rapidly succumb to. The problem, therefore, is to determine those environments where the given alloy will serve properly (and that is true for any alloy of any of the metals) and either modify it for better service in other environments, or willingly resign them to metals and alloys of another family.

A regrettable example is that chromium-nickel alloys are now practically blacklisted from marine structures because of some unfortunate failures by the pitting type of corrosion in places where stagnant sea water was in contact with 18-8 — this despite the fact that many, many times the tonnage was serving perfectly well in other applications where the sea water coming in contact with it was moving or aerated. This situation was reviewed in an editorial in METAL PROGRESS in February 1935.

More recent investigation indicates that pitting in 18-8 will occur during long exposure to many relatively weak media, including chlorides and disinfecting solutions which do not attack



Excellent Physical Properties of 24% Chromium, 12% Nickel Steel (Especially After High Anneal) Are Combined With Great Toughness, Workability and Weldability

the steels by general corrosion. Pitting may also develop at contacts with other metals or non-metals. In any event, it seems that an electrolytic cell is caused by oxygen depletion, and trouble once started is intensified by the presence of ferric chloride, a reaction product, trapped in the cavities.

Pitting type of corrosion can be caused in the laboratory by salt solutions, salts of ferric chloride or other chlorides such as ammonium, calcium, or potassium chloride. It is found that fresh sea water or sea water which has free access to air has a hydrogen ion concentration of about 7.5, that is, on the basic side. Fresh sea water, after merely bottling it and

holding for a few days, changes from basic reaction to acid reaction, and even though the hydrogen ion concentration drops only slightly, this change from basic to acid really represents an enormous change in the nature of the corroding solution. Since 18-8 resists fresh sea water with basic reaction without developing pitting or the general type of corrosion, even indefinitely in the salt spray test, the problem is to make 18-8 more noble so that it will resist the salt water solutions of slightly acid reaction.

Experiments indicated that the addition of 2 to 4% molybdenum would help quite a lot, in the sense that whereas two out of three of ordinary 18-8's could be readily caused to pit, only about one out of three or four heats containing molybdenum was susceptible. Adding a little copper helped a little more, and finally (in an effort to liberate *all* of the alloying elements and fix them in one homogeneous solid solution) the carbon was precipitated with columbium. There is as yet not enough time elapsed to say that this represents the final solution, but the case is so strong for 18-8 plus molybdenum and columbium that preliminary investigation has been warranted by the chemical industry in places where strong brines and brackish waters are handled, and these have already indicated great utility for the material. It should also be of value to the dairy industry where calcium chloride refrigerants and strong cleaning solutions are commonly employed.

Notable amounts of 18-8, strengthened by heavy cold work, have been used for deck structures in the Navy (prior to the above unfortunate occasion) and currently in the manufacture of light-weight passenger cars for high speed trains and railcars, and for truck bodies. The development of the shotwelding process, a high speed controlled type of spot welding by resistance, has permitted such fabrication of thin sheet metal.

High Ratio, Strength to Endurance

Despite strong support by one or two factors in the aeronautic industry, this type of construction has not made much headway for aircraft where strong aluminum alloys pre-empt the field. This is possibly due to the fact that too much attention is given to the so-called "strength-weight ratio." The situation is roughly that super-duralumin weighs only one-third as much as steel, and if stainless steel is to be competitive, it must have three times the ultimate tensile strength. Since nine failures out of ten in service in all mechanisms are due to break-down from fatigue rather than from over-

Controlled Spot Welding Is Utilized With Thin, Work Hardened, 18-8 Strip to Manufacture Light Weight Structures — Notably High Speed Railway Coaches. This interior of the dining car on the Santa Fe "Super Chief" shows how extra interior space is also available to increase the comfort of passengers. Photo courtesy Edw. G. Budd Mfg. Co.

powering single stress, it would be far more logical to base a comparison on the endurance ratio rather than the strength ratio.

Under these circumstances, cold-rolled 18-8 appears in a much better light. Instead of cold rolling the 18-8 so drastically to raise its tensile strength to say 175,000 psi., and thus reducing its toughness and workability to a point where it appears to be "over-rolled," or increasing the carbon content to a point where cold rolling will induce the change from austenite to martensite during the mechanical work and also embrittle the alloy, it would be better to take a well-balanced 18-8 composition, cold roll it to approximately 150,000 psi. where the impact strength and workability still are high and the endurance limit is on the order of 65,000 psi. This will then compare very favorably indeed with the endurance of duralumin 24ST, which is less than 20,000 psi.

These remarks should not be construed as a condemnation of the use of aluminum in aircraft construction. This undoubtedly is now and always will be most useful. It is desirable, however, to have alternative sources of supply for an essential industry. Strong engineering support can also be marshalled behind the position that as aircraft gets larger and larger, the relative position of the stainless steels as materials of construction becomes stronger and stronger. These points were discussed at length in METAL PROGRESS last January.

Modifications of 18-8

Before describing the iron-chromium-manganese steels, which are a new family of important possibilities, some remarks on the various modifications of 18-8 by common addition agents will be valuable.

Carbon increases the strength but decreases the corrosion resistance and high temperature stability, even though it does not harm the oxidation resistance. For wrought products, therefore, carbon is kept low and stabilized for objects which must be welded, or which serve at moderately elevated temperatures. Higher carbon with properly balanced chromium and nickel is quite suitable for deep drawing and the manufacture of articles and utensils to resist moderately corrosive influences.

Silicon increases the scale resistance by forming a tightly adhering tarnish layer, but also increases the embrittlement during heating at temperatures between 1100 and 1700° F. by favoring the transformation of austenite into ferrite. In considerable amounts it improves the weldability. More moderate percentages increase the resistance to dilute chlorides and hot, dilute sulphuric acid, but decrease the resistance to nitric acid.

Tungsten increases the creep resistance and improves the scaling resistance and hardness or wear resistance. Unfortunately, it is a rather costly addition.

Molybdenum will do almost everything that tungsten will do. Two to 4% increases the resistance to pitting, the general resistance to corrosion of sulphide liquors and hydrogen-forming acids such as acetic acid in all concentrations. However, it promotes the formation of the ferritic constituent commonly known as the delta phase, thus impairing hot work. This can be counteracted by increasing nickel at the rate of twice the amount of molybdenum — also by increasing the manganese and keeping the silicon down. Molybdenum increases very materially the creep resistance and the short-time strength at high temperature. It should be kept low in sheets that are to be hardened by cold work, as it counteracts this tendency.

Titanium is useful in stabilizing and fixing the carbon and thus decreasing the intergranular attack by wet corrosion mediums after exposure to moderate temperature. Titanium stabilizes austenite and thus enables the material to resist embrittlement after exposure at intermediate temperatures. However, it does decrease somewhat the resistance of the metal to some important acids. In the titanium-bearing steels the nickel ordinarily goes to 10%. Some difficulties have been had in introducing this metal in large American furnaces, which have not been experienced abroad on a rather smaller scale of working. An interesting application of a high titanium steel has been noted for the aircraft industry, where a surplus of titanium is introduced to convert the metal into a slightly martensitic or age-hardenable steel, thus being capable of modification by heat treatment, and giving the alloy those other characteristics of a heat treated steel, namely, a high and relatively stable elastic limit and modulus of elasticity.

Columbium, despite its relatively high price ($2.50 per lb. at present) seems to have worthwhile advantages. It does not decrease the general corrosion resistance nor the physical properties of 18-8 when used in the proper percentage. About ten times as much columbium as carbon — with carbon *(Continued on page 608)*

Corrosion Resistance of Stainless Steel

Compiled from information furnished by Allegheny Steel Co., on laboratory tests at room temperature, unless otherwise noted.

Analyses: 13 Cr has 12 to 14% chromium, 0.12% max. carbon; 18-8 has 18 to 20% chromium, 8 to 10% nickel, 0.35% min. silicon, 0.10% max. carbon.

Ratings:
0 is unaffected
1 is slightly stained
2 is stained
3 is practically unaffected
4 is very slightly attacked
5 is slightly attacked
6 is attacked
7 is pitted

Organic Substances	13 Cr	18-8
Acetone	5	0
Alkaform anesthesia		0
Benzol		0
Camphor	0	0
Carbon disulphide		0
Carbon tetrachloride	6	6
Carbon tetrachloride, vapors refluxed	4	6
Coffee	0	0
Copal varnish	0	0
Ethyl alcohol	0	0
Ethyl chloride	0	
Ethyl ether	0	0
Food pastes	0	0
Formaldehyde	0	0
Fruit juices	0	0
Furfural		0
†Gasoline	0	0
Glue	0	0
Inks	0	0
Iodoform dressing		6
Lemon juice	0	0
Lysol	6	0
Methyl alcohol	0	0
Milk, fresh or sour	0	0
Mustard	0	0
Naphtha		0
Oils, mineral and vegetable	0	0
Orange juice		0
Paraffin	0	0
Paregoric compound	2	0
Pineapple juice		0
Pine tar oil		0
Quinine bisulphate	6	5
Quinine sulphate	5	0
Rosin, molten		0
Soaps		0
Sodium salicylate	0	0
Soft soap	0	0
Soy bean oil		0
Tomato juice		0
Trichlorethylene, 100%	6	6
Tung oil		0
Vinegar, at 70° F.	2	0
Vinegar plus 0.5% salt (to 200° F.)	5	0

Acids	13 Cr	18-8
Acetic, 100%	0	0
Acetic, 33%	6	0
Acetic, 10%	0	0
Acetic anhydride, 100%	5	0
Acetic vapor, 100%	6	5
Acetic vapor, 33%	6	5
Arsenic, up to 150° F.		0
Arsenic, 225° F.		5
Benzoic	0	0
Boric	0	0
Butyric		0
*Carbolic	6	6
Chloracetic	6	6
Chloro-sulphonic, conc.	6	0
Chloro-sulphonic, 10%	6	5
Chromic, 50%		6
Chromic plus 10% potassium ferricyanide	1	
Citric	4	0
Cresylic		0
Formic		
Hydrobromic	6	6
Hydrocyanic		6
Hydrochloric	6	0
Hydrofluoric	6	6
Lactic	5	0
Lactic acid plus salt (NaCl)		6
Malic	5	0
Mixed	6	
Molybdic		0
Nitric	0	0
Concentrated HNO_3 + 2% HCl	6	6
Nitrous	1	0
Oleic	0	0
*Oxalic	5	5
Phosphoric, conc.		0
Phosphoric, 10%	5	0
Picric	0	0

Acids, continued	13 Cr	18-8
Pyrogallic	0	0
Pyroligneous		0
Stearic	0	0
Sucinnic, molten		6
Sulphuric, conc.	3	3
Sulphuric, dilute	6	6
Sulphuric (15%) plus 2% $K_2Cr_2O_7$		0
Sulphurous	5	0
Tannic	0	0
Tartaric	5	0
Uric	0	

Salts	13 Cr	18-8
Alum	5	0
Aluminum chloride		6
Aluminum sulphate	5	0
Aluminum sulphate, saturated, plus 1.0% H_2SO_4		6
Aluminum sulphate, saturated, plus 1.0% Na_2CO_3		0
Ammonium alum, saturated, slightly ammoniacal (to 200° F.)		5
Ammonium alum, saturated, acidified with H_2SO_4 (to 200° F)	5	0
Ammonium bromide	5	0
Ammonium carbonate	0	0
Ammonium chloride	5	0
Ammonium hydroxide	0	0
Ammonium monophosphate		0
Ammonium nitrate	0	0
Ammonium oxalate	0	
Ammonium sulphate	5	0
Ammonium sulphate plus 0.5% H_2SO_4	5	0
Ammonium sulphate plus 5.0% H_2SO_4	6	6
Barium carbonate		0
Barium hydrate		0
*Bleaching powder	6	6
Bordeaux mixture		0
Calcium carbonate	0	0
Calcium chlorate		0
Calcium chloride	0	0
*Calcium hypochlorite	6	6
Calcium hypochlorite made slightly alkaline with NaOH		0
Calcium hydroxide or oxide	0	0
Copper carbonate	0	0
Copper chloride	6	6
Copper nitrate		0
Copper sulphate + 2% H_2SO_4	4	0
Creosote		0
Creosote plus 3% salt	5	
Ferric chloride	6	6
Ferric nitrate		0
Ferrous sulphate		0
Glauber's salt		0
Hydrogen peroxide	0	0
Lactic acid salts		0
Lead acetate		0
Magnesium carbonate	0	0
Magnesium chloride	5	0
Magnesium sulphate	5	0
Mercurous nitrate	0	0
Mercuric chloride	6	6
Mercuric cyanide	5	0
Nickel nitrate	0	0
Nitrates		0
Nitrous acid salts		0
Phosphorous trichloride		0
Potassium bromide	6	0
Potassium chloride		0
Potassium cyanide	0	0
Potassium dichromate		0
Potassium ferricyanide, at 70° F.	0	0
Potassium ferricyanide, boiling	5	0
*Potassium hypochlorite		6
Potassium iodide		0
Potassium iodide, saturated, plus 0.1% sodium carbonate evaporated to dryness	5	

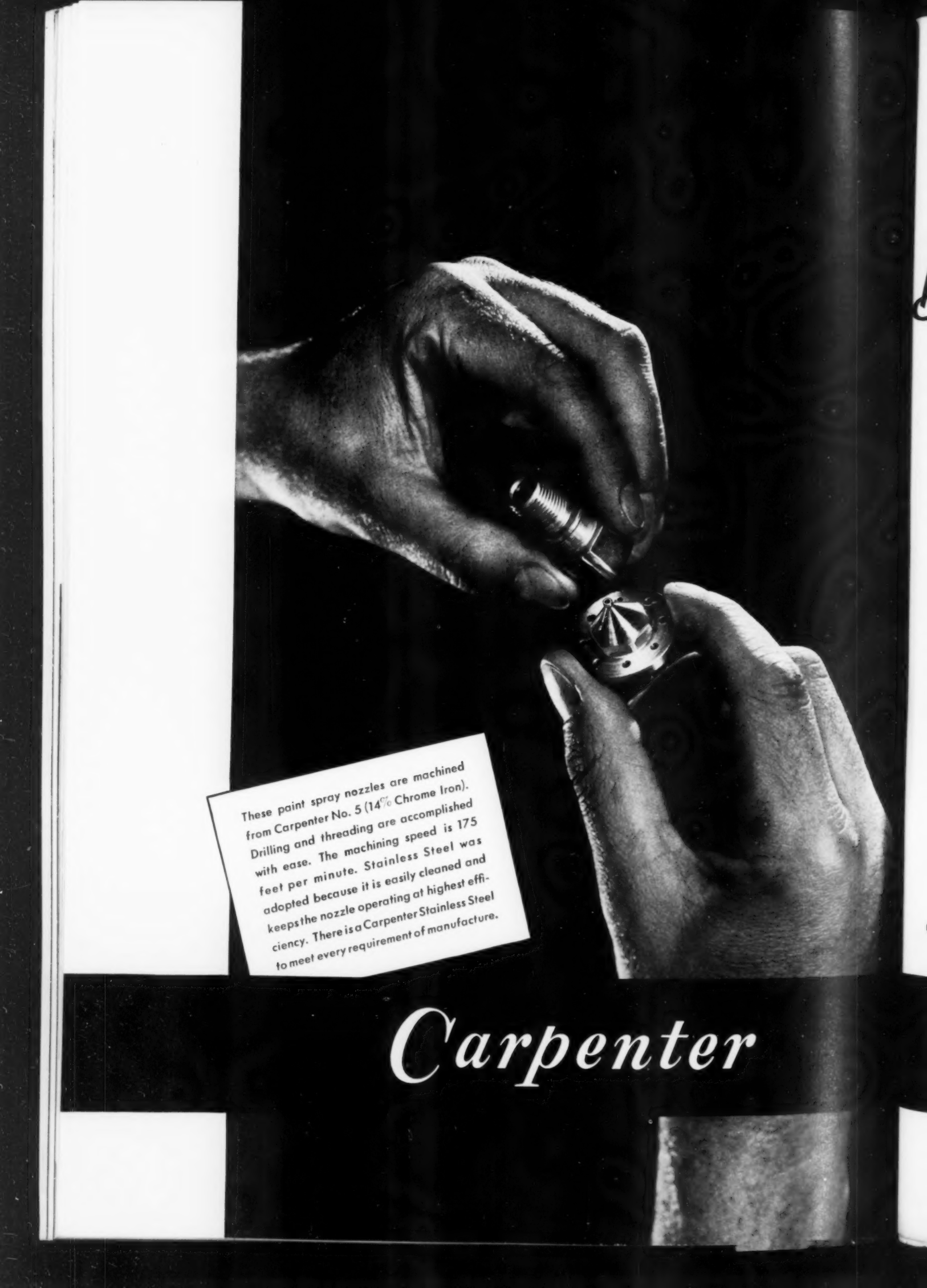
Salts, continued	13 Cr	18-8
Potassium nitrate	0	0
Potassium oxalate	0	0
Potassium permanganate		0
Sal volatile	0	
Silver bromide	0	0
Silver nitrate	0	0
Sodium bisulphate		0
Sodium bromide	6	0
Sodium citrate	0	0
Sodium chlorate, 10% solution		0
Sodium chlorate, 25% solution		0
Sodium chloride	4	0
Sodium hydroxide	0	0
*Sodium hypochlorite (Dakin's solution)	6	7
Sodium hypochlorite, saturated, slightly alkaline (to 200° F.)	5	
Sodium hypochlorite, saturated, slightly alkaline (to 100° F.)		0
Sodium nitrate	0	0
Sodium nitrite		0
Sodium peroxide, at 212° F.	6	0
Sodium sulphate	3	0
Sodium sulphide	0	0
Sodium sulphite	0	0
Sodium thiosulphate plus 4% potassium meta-bisulphate	0	0
Sodium thiosulphate, 20%, plus acetic acid, 20%	6	0
Soda ash, 10% (to 200° F.)	0	0
Soda ash, 50% (to 200° F.)	0	0
Spirits of nitre	0	0
Stannic chloride		6
Stannous chloride	6	5
Sulphur, molten (400 to 500° F.)		0
Sulphur chloride		5
Titanium tetrachloride		0

Miscellaneous	13 Cr.	18-8
Aluminum, molten		6
Ammonia, gas or solution		0
‡Atmosphere of steam, carbon dioxide and air	5	0
‡Atmosphere of steam, sulphur dioxide, carbon dioxide and air	5	0
Baking oven gases	0	0
Baking oven gases, hot		2
Bromine	6	6
Bromine water	6	6
Cadmium, molten		6
Chlorine gas, wet and dry	6	6
Copper sulphate electroplating solution		0
Copper cyanide electroplating solution		0
Gold cyanide electroplating solution		0
Hydrogen sulphide, (to 400° F.)		0
*Iodine	6	6
Lead, molten		6
Methyl chloride, gas		0
Mercury		0
Mine water	0	0
Nickel sulphate electroplating solution		0
Sauer kraut brine		6
Sea water	6	7
Silver cyanide electroplating solution		0
Steam and air, refluxed	4	0
Sulphur dioxide		0
Syrup		0
Water (potable)	0	0
X-ray developing solution		0
Zinc, molten	6	6
Zinc chloride	5	

*Chemicals frequently used as sterilizing reagents. 18-8 is unaffected by such reagents over short periods of exposure (up to 4 hr.) but is not suggested for storage containers or applications involving continuous exposure.

†Gasoline containing anti-knock lead compounds attacks 18-8 under some circumstances.

‡Air bubbles in many stagnant solutions may cause pitting attack.


These paint spray nozzles are machined from Carpenter No. 5 (14% Chrome Iron). Drilling and threading are accomplished with ease. The machining speed is 175 feet per minute. Stainless Steel was adopted because it is easily cleaned and keeps the nozzle operating at highest efficiency. There is a Carpenter Stainless Steel to meet every requirement of manufacture.
Carpenter

Because it machines easier!

Ask a production man his reason for choosing Carpenter Stainless bar stock ... and invariably back comes the answer, "Because it machines *easier.*"

So often does this answer come, and from so many different types of plants, that it constantly confirms everything we have ever said about Carpenter Free Machining Stainless Steel.

This ease of machining opens the door to many additional uses for stainless steel. Manufacturers are now finding it possible to give their products more complete protection from corrosion. Parts that were previously considered too difficult, and therefore, too expensive, to make of Stainless, are now being turned out *economically* through the savings afforded by Carpenter Free Machining No. 5.

Carpenter No. 5 was used for the parts shown in the photograph. Note the clean machining obtained at a cutting speed of 175 feet per minute. In addition to faster production and lower machining costs, the fine, smooth finish developed by this Stainless saves hours of time where polishing is required. When super-corrosion resistance is called for, Carpenter No. 8 —a free-machining 18-8 grade containing Selenium—supplies the answer.

The Carpenter representative with his specialized knowledge of Stainless Steels is prepared to help you select the grade best suited to your particular requirements. His experience on many different types of problems enables him to help you lower your cost of handling Stainless Steel. Get the benefit of this experience by taking up *your* problem with him.

more than corrosion resistance

THE CARPENTER STEEL COMPANY, READING, PA.

STAINLESS STEELS

Stainless Steels

(Cont. from page 604) 0.10% max. and columbium 1% max. — gives a steel which is resistant to intergranular attack at all temperatures between 600 and 1550° F. Such an alloy also retains its toughness after long exposure at 1200° F. (thus acting much as described above for 4 to 6% chromium steels), the Izod impact remaining at 100 ft-lb. or more. In columbium-treated 18-8 it is also desirable to increase the nickel to perhaps 10% in order to counteract any tendency for the formation of ferrite. Up to 90% recovery of the alloy is obtained during melting, and scrap containing columbium can be remelted with recovery of three-quarters of it.

Selenium has been used very successfully to improve the machinability of steels, as in the manufacture of screw machine products, and reduce their galling or seizing tendency.

Chromium Steels With High Manganese

Work on the chromium-manganese steels was started by Becket as far back as 1912, and in 1920 an alloy was patented having around 25% chromium and half as much manganese — an austenitic alloy of high permeability and unusually suitable for electrode holders.

Later work has been done to develop an alloy having a high degree of stain resistance and maximum drawing properties. More interest has been exhibited in Germany, where there is an acute shortage in nickel, but a considerable amount of sheet has been produced even in this country.

Manganese and nickel are both austenitizing elements, but manganese is only about half as powerful as nickel. A further difficulty in the use of manganese alone is that either the austenite or ferrite tends to precipitate a brittle constituent (possibly an iron-chromium compound). The result is that the useful compositions are fairly narrowly restricted.

Probably the best combination is close to the well-known 18-8 proportion — namely, 18% chromium, 9% manganese, and carbon less than 0.10%. These alloys are not wholly austenitic even when quenched from the optimum temperature, namely, 1850° F. However, in this condition the metal is quite weldable, has a high Erichsen value (in the neighborhood of 10 in the form of 22-gage cold-rolled sheet), a Rockwell hardness of B-80, an Izod impact of more than 100 ft-lb., and an ultimate strength of 110,000 psi. — truly a notable combination.

Since this metal is more easily hot worked than the plain iron-chromium alloys, it is a material of very attractive possibilities. When properly annealed and descaled (with a hot solution of 2% hydrochloric acid and 7% nitric acid), it is more resistant to atmospheric corrosion than the 18% chromium alloy although not as good in general corrosion resistance as 18-8; still it is excellent for many common weak acids, both organic and inorganic. It is particularly resistant to hot sulphur compounds. Its creep resistance is not as good as 18-8 chromium-nickel, and it is subject to intergranular corrosion by strong solutions after heating at intermediate temperatures (but this trouble is cured in the same way, by stabilization of the carbides).

While it is not as good as 18-8 in moderately hot service, it is more stable under constant or intermittent service at 1650° F., retaining its ductility unimpaired under these circumstances. In other words, even though the austenite in Cr-Mn steels does appear to be unstable at intermediate temperatures, it has exceedingly good properties when hotter.

Manganese Promoted in Germany

Stability of the Cr-Mn-Fe austenite can be increased by adding either copper or nickel. There is a definite limit to the copper addition on account of liquation and hot shortness. One per cent gives approximately the maximum increase in ductility. Nickel not only stabilizes the austenite but also increases its proportion, and can alloy in unlimited amounts. It therefore works out that the 18% chromium, 9% manganese, plus 1.5% nickel is much used in Germany. If nickel is increased to 5% the manganese can also be reduced to 5% so that an alloy containing 18% chromium, 5% nickel and 5% manganese is the equivalent of 18% chromium, 8% nickel for workability. An even higher degree of workability is had if 1% copper is added to this composition.

In conclusion, it might be remarked that an alloy wherein the proportions are reversed, namely, 16% manganese and 9% chromium, with 1% molybdenum, has been promoted in Germany for deep drawing purposes in the manufacture of domestic ware and for other uses where mild corrosive media must be resisted.

WHERE DO WE GO FROM HERE?

Editorial Comment

DURING THE SUMMER the National Resources Committee submitted to President Roosevelt a study called "Technological Trends and National Policy." The portions on the mineral industries and metallurgy have appealed to Myron Weiss ✠ (associate editor of *Time*) as quite significant, and he digested these two chapters for possible use in METAL PROGRESS. Even Mr. Weiss's digest is too long for printing in full. From it certain important items can be quoted; remarks not in quotes are by the Editor.

As to the oft-expressed fears that our resources of raw materials are nearing exhaustion, the Committee states:

"If discovery of new deposits should cease today, proven reserves in the United States would meet the requirements of this country for a period ranging from perhaps ten years for petroleum to probably more than 2000 years for coal. However, discovery will not cease in any predictable time. . . . There seems little escape from the prospect that mining in the future must adjust itself to greater depths or lower grade ores, or even to both. It is in the case of lead and zinc that we should expect to perceive the earliest developments of general trends in mining techniques to meet the changing conditions forecast by depletion. . . . Another solution of the growing difficulties of mining is the use of techniques which produce ore of lower grade at a decreased cost. The invention of flotation, one of the main factors that has made possible the working of low grade ores, has proved to be among the most important developments in the history of metal mining. . . . For this and other reasons there is a growing ability to treat complex ores containing several metals and to separate them successfully."

In other words, we have since the turn of the century, by the perfection of our digging equipment, our concentration and separation devices, our smelting, leaching and electrolytic recovery, so far been able to cope with the steady depletion of our high grade minerals, as the result of hundreds of detailed refinements in old processes rather than the discovery of any radically new thing excepting flotation.

So much for the minerals we have. How about those we have not?

"There is no definite list of strategic minerals, substances of which our requirements, previous to the War, had been wholly or largely supplied by imports from abroad. At present the American list includes manganese, for steel; tin, for food containers; mercury, for detonators; tungsten, for high speed toolsteels and electric light filaments; chrome ore, for chemicals and metallurgy; platinum, for catalyzers; nickel for alloys. . . . In some cases there is a fair probability that processes can be developed for converting the kind of material we can produce into the grade that industry demands; in others there seems little possibility of such a result. Changing the technique of the consuming industry so as to use the materials we have has been the most fruitful of results so far. No major developments, from the mining standpoint at least, seem to be in easy reach."

The above rather pessimistic view from the chapter on Mineral Industries, written by Frederick Gale Tryon of the U. S. Bureau of Mines and others, is a better appraisal of the situation, in the Editor's opinion, than the following from Clifford Cook Furnas's chapter on Metallurgy. (Dr. Furnas is associate professor of chemical engineering at Yale University.)

"An unbiased survey shows that, if we were suddenly shut off from the world markets, it would be possible to take care of necessities with our home resources if we should apply existing knowledge of metallurgical processes to the working of low grade ore deposits, and possibilities for substitution of one material for another."

Very good — if *time* were available, but anyone who was mixed up with ordnance during the War knows that *time* is the one thing you mostly have not. It has taken us just about 20 years to substitute molybdenum (of which we have plenty) for tungsten (of which we have relatively little) as an alloying element, and no amount of time would be sufficient to make molybdenum into a satisfactory lamp filament.

Urged by war necessity and ample subsidies, development of known deposits of low grade ores will be matters of months rather than years, for the sinking of shafts, the driving of tunnels, the building of reduction plants, the perfecting of processes all take time.

Consider manganese as an instance. By far the most important of our "strategic" metals, nothing fundamental continues to be done about our own deficiencies. Uncle Sam shows no interest in the oft-made proposal of importing a surplus of high grade ore for a stock pile against the inevitable emergency. Neither is the steel industry doing anything observable toward the commercial development of some of the likely looking proposals for converting low grade ore (of which we have much) into high grade ferromanganese. The latter is truly a surprising situation in view of the care with which the steel masters acquire and safeguard their iron ore resources.

"As in every other line of industrial activity, the most noticeable trend in the metallurgical industries has been the increased efficiency of production. One item seems to stand out very clearly, namely, that the production of the various metals is becoming more and more of a complicated business. One of the major effects of this tendency has been, and will continue to be, a distinct change in the type of personnel required, requiring an increasing number of high caliber, technically trained men. As processes become more and more complex, they progressively require more expensive equipment and personnel and hence tend to be a barrier in the way of small producers. The improved mechanical techniques all seem to be pointed toward labor saving. This tendency will unquestionably enter the picture of technological unemployment."

In Dr. Furnas's view, the trends therefore merely extend those observable at present and in the recent past — that is to say, a greater diversification of alloys, improved in quality, at lower costs and with less labor. He sees no prospect for any direct process of making steel from ore, but is charmed by the proposal to produce sheet by pouring molten metal between water-cooled rolls. He finds no revolutionary change in metallurgy in sight.

Anyone who would criticize this lack of prophetic vision should try it himself. He would conclude that world-wide industrial revolutions have come about from discoveries of new *sources* of power: First was man power, then beasts of burden, then after thousands of years was water power, then steam, then electricity, then internal combustion. What is there left? We might hazard four guesses: Tides, direct radiation (sunlight), internal heat of the earth, atomic disintegration. When any one of these gets to the operating stage, prepare to revise all old concepts of economics and production.

Another thing which is characteristic of outstanding technologic advances — at least as far as the recent ones in metallurgy are concerned — is that they violate established concepts so grossly as to appear, at first sight, to violate the fundamental laws. Revolutionary discoveries wait until the inventor starts to think in an opposite direction to the line taken by his contemporaries and all his predecessors.

Take, for instance, flotation, the sole improvement of fundamental importance to the mineral industries since the turn of the century. Prior to its discovery, the whole art of ore dressing, of separating valuable minerals from worthless gangue, depended on the fact that one was heavier than the other and the heavy one could be made to sink. Flotation so violates fundamentals that the heavy one is made to float!

Discovery of high speed steel, another of our epoch makers, really involved the discovery of a heat treatment — a heat treatment so bizarre that anyone would have told you that the tool would be ruined beyond repair!

Hardened aluminum is an invention no less important than high speed steel, since it not only made available the necessary light metals for aviation, but also has influenced fundamentally the whole science of metals. Yet it was done by a mild reheating that any fool knew would temper and soften a quenched metal rather than harden it.

To render iron a noble metal — proof against scaling by hot gases, rusting by the elements, or corrosion by acids — sounds as silly as making a silk purse out of a sow's ear, yet two metals, chromium and silicon, neither of them noble, do it. Enter the stainless steel age!

Maybe we are too close to this event to view it in its proper perspective, and the same might be true of the rise of the welding processes, which might be classed as the most recent of our fundamental advances. Here, too, the paradox persists that the most brutal imaginable treatment of good metal results in strong, reliable joints.

Casting our minds along this procession of flotation, high speed steel, hardened aluminum, stainless and welding, and attempting to project them into the future indicates only one thing clearly: That the really fundamental advances will come when someone pulls his mind out of the rut that every other mind in creation is following, and goes off in an entirely different direction. *That* takes courage to the extent of fool-hardihood!

CONVENTION COMMENT

notes of a busy week

VIEWERS WITH ALARM and doubting Thomases were unusually vocal when Atlantic City was chosen for the site of the 1937 ⊜ convention and exhibition. Never before had any of the 18 predecessors been held outside an industrial region. Nevertheless the National Metal Exposition has grown to such dimensions that halls large enough to house it can be counted on the fingers of one hand — and of these the Auditorium in Atlantic City stands pre-eminent. Likewise the number of visitors has grown to a formidable number for hotels to house in addition to regular patrons. Here again the choice was fortunate in finding the resort off-season; headquarters hotels of each of the societies were filled to capacity, but additional accommodations were readily secured in good ones nearby. It was as though Atlantic City had re-opened for your benefit; motley crowds on the boardwalk were replaced by groups of your own acquaintances. Looking backward, therefore, it is clear that the choice of convention city would certainly be approved by those fortunate enough to be there.

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FOR THE FIRST TIME the Exposition was restricted exclusively to members of cooperating societies and invited guests, locking out swarms of the idly curious. Registration at 11,000 constituted no record for numbers, but undoubtedly reached an all-time high in quality. While an analysis of the cards has not yet been made, it is certain that more ⊜ members attended than ever before. American Welding Society's Miss Kelly also reports a new record by an even hundred. Registration of the two metal divisions of the American Institute of Mining and Metallurgical Engineers has been exceeded only once, says John Breunich of the headquarters' staff.

HONORS for meritorious contributions to the science and art of welding, in the form of the Samuel Wylie Miller medal, were awarded to H. Sidney Smith, chief engineer of the Prest-O-Lite Co., and consulting engineer for Union Carbide Co. A lifetime in England and America, where he came in 1911, has been spent on the production and safe handling of dissolved acetylene, and as an offshoot from this he has made significant contributions to industrial safety and fire prevention. Among his other honors have been the presidency of the British Acetylene Association, the International Acetylene Association, and the Compressed Gas Manufacturers Association.

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THREE of the societies recognized the outstanding merit of technical contributions to their published records by appropriate medals and scrolls. The Henry Marion Howe medal for the outstanding paper in ⊜ **Transactions** for 1936 was awarded to "X-Ray Investigation of the Iron-Chromium-Silicon Phase Diagram," by A. G. H. Andersen, director of the research department, Phelps Dodge Corp., and Eric R. Jette ⊜, associate professor of metallurgy in Columbia University. Wire Association's medal went to "Abnormal Grain Growth and the Annealing of Low Carbon Steel Wire," by Benjamin L. McCarthy ⊜, chief metallurgist of Wickwire Spencer Steel Co. — the second time for "Mac," who announced that hereafter his papers could be printed but not considered in competition. The best paper published in the American Welding Society **Journal** was judged to be "Welding in Tanker Construction," read at the Thursday session by T. M. Jackson, chief electrical and welding engineer of Sun Shipbuilding and Dry Dock Co., and it was therefore awarded the Lincoln gold medal.

REPORTS of ⊜ officers at the annual meeting note an unprecedented growth of Society affairs in almost all directions. President Bain stressed the educational activities of the various Chapters, noting the fact that the enrollment in such courses totaled no less than 4000 members. In this vein he awarded the President's Bell for outstanding services to the Philadelphia Chapter, the citation being "not only for excellent educational work, not only for an inspiring sponsorship of studies at Temple University, and not wholly for the making available by publication of its exceedingly fine lectures on fundamentals — but rather for sustained quality of excellence, maintained at a mark set some ten years ago."

Membership is now over 10,000, an increase of one third over that a year ago. During President Bain's incumbency four new Chapters and three student groups were organized, bringing the number from 42 to 49. The new Chapters are "Puget Sound" at Seattle, "Oregon" at Portland, "Texas" at Houston, and "Calumet" at Hammond, Gary and East Chicago. The new student groups are at Virginia Polytechnic Institute, Michigan College of Mines and Technology, and Missouri School of Mines and Metallurgy.

Secretary Eisenman dwelt upon the activities of the central office and its various supporting committees, calling particular attention to the fact that gross expenditures per member are about $32, which is $22 more than the annual dues, this additional $22 being obtained from the conventions, advertising, books and periodical sales. Four sectional meetings were held during the last winter; next spring a Metal Exposition and Congress will be held in Los Angeles, the dates being March 21 to 25. He also announced that next year's convention will be held in Detroit the week of October 17.

Treasurer Woodside summarized the audited balance sheet showing income for the last fiscal year of $297,508.03, expense $252,197.18 (both figures exclusive of $40,497.56 returned to chapters) and net gain $45,301.85. Total assets of the ⊜ are about $300,000, of which $200,000 is classed as "surplus." Securities owned have a market value of $181,416.61. Audited reports from Chapters show a total of about $60,000 additional assets held by them.

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TECHNICAL MEETINGS held satisfactory audiences, although these would have been even better if so many demands had not been made. Twice a day from Monday morning to Friday afternoon, the seeker after knowledge had to make choice among from two to six opportunities. No less than 116 papers were presented for discussion; a more satisfactory result for all concerned would ensue if only the outstanding ones were chosen and featured.

LAST YEAR the Board of Trustees invited six secretaries of Chapters who had served ten years or more in that capacity to be guests of the ⊜ at the Convention, Messrs. Handy, Matthews, Peterson, Walker, Caswell and Holden. This year another name was added to that roll — Fred M. Reiter of the Dayton Chapter, and he was present as the honored guest of the Society.

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HERCULEAN was the job courageously attempted by Earnshaw Cook to discuss in five short lectures the whole subject of openhearth steel making; an appreciative class of 200 attended. More informal were the three discussion conferences led by J. R. Vilella on what to do and what not to do to improve metallographic technique. Exhibits of good and bad work, due to adherence or neglect of this, that or the other precaution, were exceedingly instructive.

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THIS COMMENTATOR, long a guerrilla warrior for more comfort and better ventilation in meeting rooms, can report a simultaneous high and low. The ballroom at the Auditorium was so large that it could not be fouled by a normal amount of tobacco smoke and the congregation rested all too comfortably in Morris chairs and over-stuffed davenports. Meeting room B, on the other hand, was low ceilinged, sealed against entry of that well-advertised sea air, and furnished with folding chairs hardly less comfortable than found at a bridge benefit.

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ON THE OTHER HAND, the Exposition was wonderful, by common acclaim the most colorful and brilliant by far — an amazing change from the comparatively drab appearances of only three or four years ago. Superlatives are warranted, for the high arched roof lent a spacious feeling; ventilation was perfect so the many operating furnaces caused no discomfort; some acoustic trick quieted down the normal noises. So many well-designed and executed showings met the eye that comparisons are invidious. Those which, like the welding contingent, had operating exhibits relied upon motion to catch the passing eye; others, notably the metal producers, utilized artistically colored backgrounds — even elaborate stage sets — to house and set off their products.

Cut-away models, full size, of furnaces heating by convection (such as Leeds and Northrup's Homo and Lindberg's Cyclone) were notably informative. In the elaborate exhibit of Republic Steel could be found a full-sized cross section of a railway coach

made by Budd of stainless steel. General Electric had a working line-up of scale-free hardening equipment on drill chuck parts. Among other operating exhibits might be mentioned bright zinc plating by Du Pont; localized heating by high frequency induction by Ajax Electrothermic; Holden's series of four salt baths for molybdenum high speed steel — preheat, high heat in ceramic pot, quench, let down; Youngstown's continuous mill for cold rolling; Hayes' tube furnace simply made of a hollow Globar and serviced by a small sized gas preparation unit; Bethlehem's operating model of a heat treating plant for alloy bars. Whether it was because this reporter played with block letters in his babyhood, or because of the stark simplicity of the huge letters, the TIMKEN booth keeps recurring to mind.

TO THIS OBSERVER, the clever puppet show on the Auditorium's stage, created by Tony Sarg no less, was the high spot of exhibitionism; it relied upon the most ancient showmanship of universal appeal. The story of how the Tip-Top Tool Co. (no, not Fool Co.) was rescued from an inferior steel, and of Dr. Fixit of Carnegie-Illinois metallurgical service who saved the day for Tip-Top and gained a large order for Carilloy, and the harrowing experiences of the animated connecting rods, both good and bad, in the good Doctor's testing machinery, sounds trite enough, but — most everybody saw the show at least twice.

We are still puzzled: How could so many jesting lines get by the top executives at 71 Broadway? For most of their ilk appear to have left their sense of humor on the second or third rung of the ladder on the way up — at least as far as their own business is concerned. Maybe they sat down and saw the show! We observed a fascinated father and son at one performance, and the same merriment was spread broadly over the faces of both 40- and 8-year old.

IT IS BAD ENOUGH to be expected to diagnose unerringly the minor ailments of the family motor car, so this metallurgist declined to expert the radio and its inner workings. It would now appear that a much closer acquaintance with the whole subject of electronics is really necessary, now that vacuum tubes are used in inspection machines, pyrometric indicators and heat controls, to say nothing of resistance welders. Howard Scott assured us that the tubes in the latter (so neatly taking a sine wave apart and shooting bits of it into lapped stainless sheets and aluminum) exhibited by Westinghouse were good tubes containing as they did considerable of the alloys konel and kovar (he couldn't have said "fernico") . . . . A. O. Smith also showed a magic box with a pointer to be set at the correct voltage for a welding arc, as determined by the supervisor for the given rod, covering, and size of joint, whereupon signal lights show — one when the arc is too short, one when the arc is too long, none when the arc voltage is correct to within one volt plus or minus. Likewise a pair of flashlight bulbs in either cheek of the operator's helmet tell him the same story in the corner of his eye and without distracting his attention from the actual job. Truly an important aid to learners, to old hands for periodic check-up or for guidance with unfamiliar electrodes, and for constant supervision on all work of critical nature.

A YEAR OR SO AGO Leon Bibber left the employ of the U. S. Navy for that of Big Steel, but apparently took with him some remembrances of explosion bulkheads and bulbous warship bottoms, for now we find him testing welded drums by filling them with water, lowering in an explosive cartridge, running for a bomb-proof and pressing the button. An improvement on Old Faithful geysers out the open top of said drum and (if tough enough) it assumes a shape exciting ribald comment. Just another one of those impact tests!

THIS MULTIPLICITY of tests is wearisome to the spirit, so Horace Knerr assures us that his is no new test, just a new Brinell tester. Knerr's slogan, as you may know, is "You can make it lighter of heat treated alloy steel," and he proves the point by replacing cast iron and cast steel with the above-mentioned material and a 3000-kg. tester with 10-mm. ball emerges weighing only 30 lb. While it is capable of handling work of moderate size, a simple strong-back will adapt it to the testing of anything up to armor plate and 18-in. guns.

IT IS NO NEWS that the Editor is an admirer of the heat and corrosion resisting alloys of chromium, nickel and iron. Cast, forged and welded into furnace parts, they are responsible for our present highly developed art of heat treatment. Too often, though, they fail because of unfair circumstances — it is difficult enough to resist hot oxygen without having to strain against unequal expansions, warped furnace bindings, rigid fixtures or a swelling load. Hence it was good news to find a number of new and intelligent designs evolved by General Alloys' staff for chains, trays, boxes, beams and conveyors, in every one of which the alloys are given a chance to work without handicap.

STARTING A LOAD THROUGH GAS LOCK IN A FURNACE WITH CONTROLLED ATMOSPHERE. PHOTO BY ROBERT Y. RICHIE AT REED ROLLER BIT CO.

CARBON-FREE ALLOYS

hard as toolsteel

Summary of Campbell Memorial Lecture

By Wesley P. Sykes
Metallurgist, Cleveland Wire Works
General Electric Co.

IRON-COBALT-TUNGSTEN alloys, whose structure and hardening characteristics were the subject of the Campbell Memorial Lecture, form an important family of cutting tools, first described as "Alloy 548" by Zay Jeffries and W. P. Sykes in METAL PROGRESS, February 1933. Continuous study in the intervening years has enabled Mr. Sykes, the lecturer, to present a much more comprehensive view of the ternary equilibrium diagram than available in 1933, but that portion of his lecture is too extensive for brief abstract. The present aim will be to show how he correlates the hardening reactions of certain of these carbon-free alloys with those of our fundamental cutting tool, namely high carbon steel.

It has become customary to look upon the hardening of alloys (even of steel, the iron-carbon alloy) as manifestations of a general phenomenon — precipitation from a super-saturated solid solution. It is true that many non-ferrous alloys can be hardened very usefully by a high temperature solution heat, then quenching to fix this condition, and finally reheating moderately to allow the metastable solution to precipitate a shower of submicroscopic particles. However, the degree of hardness achieved by such methods is in nearly all cases far inferior to that after quenching and tempering a high carbon steel. On the assumption that the hardening of steel is only a special case of the general principle of precipitation hardening, the question may reasonably be asked, "Why is this special case so outstanding in the result?"

In the latest edition of The Metallography and Heat Treatment of Iron and Steel, Dr. Sauveur discusses martensite and the hardening of steel and remarks: "In no other alloy does the solvent undergo an allotropic transformation in the quenching bath, a transformation which is accompanied by a great fall in solubility. In no other alloy is so excessive a degree of supersaturation created by quenching. . . . To express it differently, the urge to age on the part of an excessively supersaturated solid solution of carbon in alpha iron is so great that aging starts at once, whereas in solid solution of non-ferrous metals no such urge exists — hence time and even increased temperatures are required to cause precipitation."

In his lecture Mr. Sykes shows how the same combination of allotropic transformation and fall in solubility occurs in a ternary, carbon-free alloy, and not only matches the hardness of quenched, high carbon steel, but also duplicates the microstructures!

Of several alloys available, the one chosen for this summary contains 30% cobalt, 20%

tungsten and 50% iron, made from chemically purified oxides, reduced, melted and heated under hydrogen, so that the carbon content is less than 0.01%. In what follows it will be termed "the alloy." It solidifies as a gamma solid solution — that is to say, a single phase alloy of face-centered cubic crystallinity. On cooling to about 1390° C. (2530° F.) an excess constituent called epsilon phase puts in its appearance, and increases in amount as the temperature falls — that is to say, the solubility of epsilon in gamma decreases with temperature. (Epsilon has been shown to be a mixture of two intermetallic compounds, Fe_3W_2 and WCo, which are isomorphous and crystallize in the trigonal system.) On cooling through the range 965 to 940° C. (1770 to 1720° F.) the gamma solid solution changes to an alpha solid solution — that is to say, recrystallizes into body-centered cubic. Furthermore, alpha has a considerably less solubility for epsilon than the gamma phase from which it was formed, and this solubility also decreases with temperature.

One does not need to emphasize the similarity of these structural changes on cooling with those of a hyper-eutectoid carbon steel other than to list the data, as in the tabulation on this page. Using the analogy to high carbon steel, the microstructure after various common heat treatments may be anticipated. In the words of the lecturer: "In cooling to room temperature even by drastic quenching the gamma is so thoroughly converted to the low temperature alpha form that the X-ray is unable to detect any residue. As previously mentioned, this lattice change imparts to the final alpha structure the Widmannstätten pattern [shown in the top view on page 651] and results in a considerable increase in hardness (Rockwell C-38). With very slow cooling from 1400 to 1100° C. (2550 to 2010° F.) the gamma grain boundaries are outlined by a thick network of epsilon precipitate and within the gamma grains this phase segregates as long needles forming once again this well-defined Widmannstätten pattern."

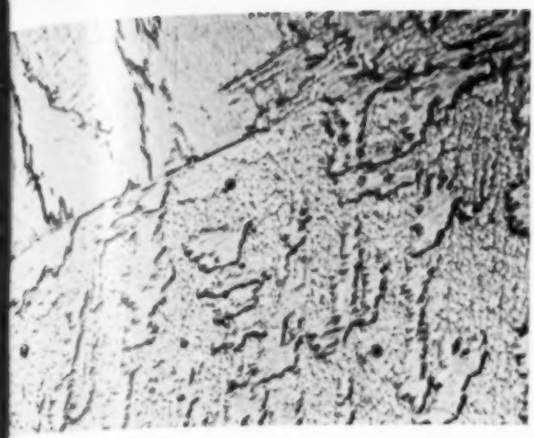
Slow cooling through the transformation and then holding 20 hr. at each of the subcritical temperatures 925 and 900° C. before quenching, gives highly dispersed epsilon, precipitated during the gamma-to-alpha transformation and growing in size at the long stay at about 900° C., as shown in the third view. Again using Mr. Sykes' words:

"Thus far in order to identify readily the existing phases we have been concerned with structures formed under conditions approaching equilibrium — that is, resulting from extremely low rates of cooling. Following the trail blazed by Davenport and Bain, we may arrive at a fuller understanding of the time-temperature relations governing the gamma-to-alpha transformation by causing this reaction to proceed isothermally and observing the accompanying volume change. Thus by rapidly transferring the alloy specimen from some predetermined temperature within the gamma range to a dilatometer maintained at the desired constant temperature, expansion is observed to begin after a certain lapse of time."

The time required for the onset of the transformation in a given alloy depends upon, first, the temperature of initial heating and, second, the temperature of the quenching medium. Examples of isothermal transformation at four temperatures were given by the lecturer. After heating for 1 hr. at 1300° C. (2370° F.) the sample was quickly transferred to the dilatometer at the designated temperatures; plainly the beginning of expansion is delayed more and more as the temperature of decomposition is lowered.

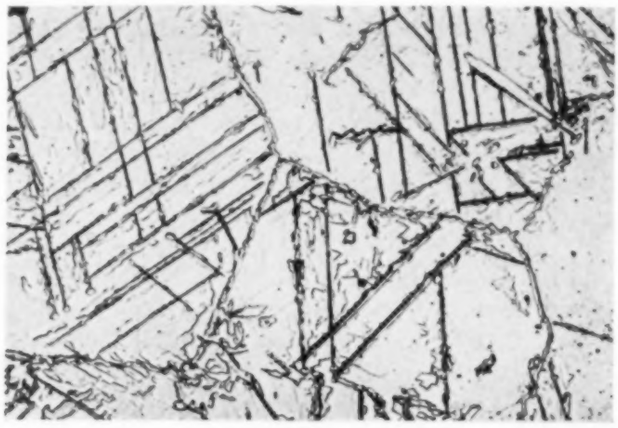
The so-called "S" curve of subcritical transformation is shown in the diagram on page 652. Points on Curve *C*, representing completion of reaction, may be estimated from the micro-

	30:20:50 Co:W:Fe	1.2%C Steel
Freezing completed	2660°F.	2300°F.
Structure	Gamma solution	Gamma solution (austenite)
Excess constituent appears	2530°F.	1690°F.
Constituent	Fe_3W_2·WCo (epsilon)	Fe_3C (Cementite)
Solubility just above transformation	10%W	0.83%C
Transformation range	1770 to 1720°F.	1335°F.
Transformation product	Alpha solution	Alpha solution (ferrite)
Solubility just below transformation	6%W	0.03%C
Solubility at room temperature	4%W	0.01%C



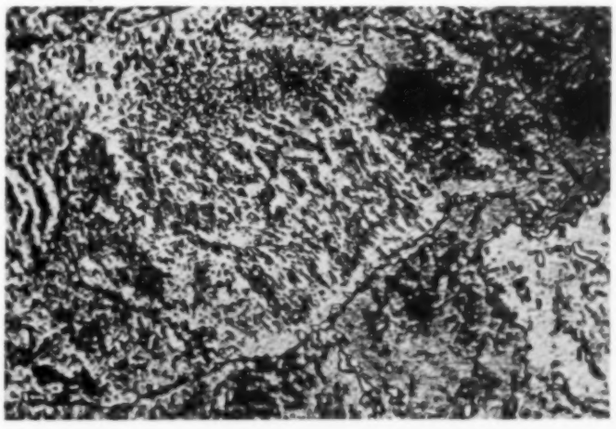
If Water Quenched as a Gamma Solid Solution, It Transforms to Alpha With Widmannstätten Markings Imposed by the Gamma Crystallinity

rounded particles like the nodular pearlite ('troostite') in high carbon steels. After an hour at 900° C., the decomposition is nearly complete, as shown by the etched microsection at the bottom of page 652. In the few gamma areas remaining we see a scattering of epsilon particles which have attained visible dimensions. It is evident, therefore, that in the decomposition of gamma at 900° C., the allotropic transformation is preceded by precipitation of epsilon, the excess constituent. The lamellar nature of the decomposition products is clearly revealed; the details are better shown in another alloy (20% Co, 10% W) after similar heat treatment."



If Slowly Cooled, Taking 60 Hr. to Reach 1100° C. (Above Transformation, and Then Fixed by Quenching), Excess Epsilon Constituent Is Precipitated at Gamma Grain Boundaries and Within Gamma Grains on Crystal Planes

Hardness changes accompanying decomposition at constant subcritical temperatures are shown on the semi-logarithmic plot, time vs. Rockwell hardness, C scale, at the top of page 653. In the initial horizontal portions of the heavy curves for 900, 750, 600 and 500° C. may be recognized the time interval preceding the start of reaction. Once under way the hardening cycle rapidly reaches a maximum at

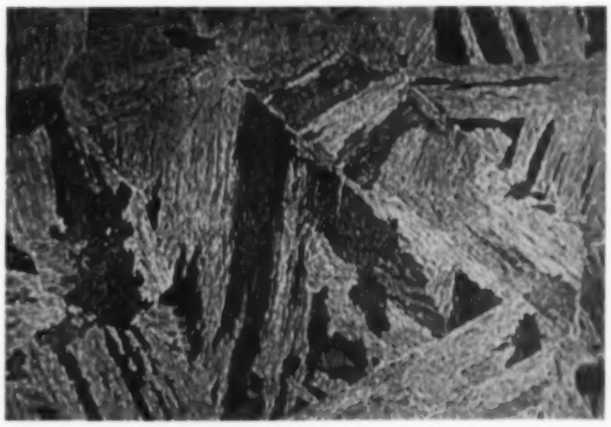


Left; If Slowly Cooled Below the Transformation Temperature, Gamma Changes to Alpha, and Particles of Epsilon (Less Soluble in Alpha Than in Gamma) Grow to Considerable Size in the Alpha Grains

structure or (if below 600° C.) from the extent to which the alloy develops its full hardness upon directly transferring to 600° C. from the temperature of isothermal transformation.

"In order to follow the changes in structure and hardness which accompany the isothermal transformations we have only to quench small blocks of the alloy from a selected temperature within the gamma range, using as a quenchant some liquid medium maintained at the desired temperature of transformation between 900° C. and 100° C. By withdrawing specimens from the bath at intervals and water quenching we may follow the progress of the reaction from the accompanying microstructures. As quenched from 1300° C. into molten salt at 900° C. (1650° F.), held at that temperature for 10 min., then water quenched, the resulting structure shows white areas, grains of gamma which were still intact at 900° C. but which, of course, changed to alpha during the quench to room temperature, outlined with rapidly etching

Below; If Water Quenched and Then Tempered 5 Hr. at 600° C., the Hardness Is C-67 and the Structure Is "Martensitic," Fine-Grained Alpha With Submicroscopic Epsilon Dispersion

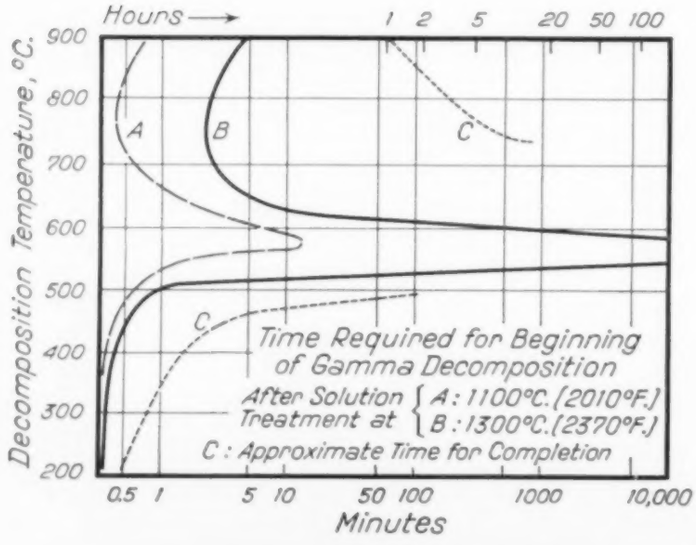


900° C., and less rapidly at 750° C., and then falls away. Prior to the completion of the gamma-to-alpha transformation (the peak of the hardness curve corresponds to the complete microstructural change), the measured hardness after quenching to room temperature is the resultant of two structures, the alpha solid solution which transformed only during the final cooling and the duplex structure of alpha and epsilon formed from gamma during the stay in the hot salt.

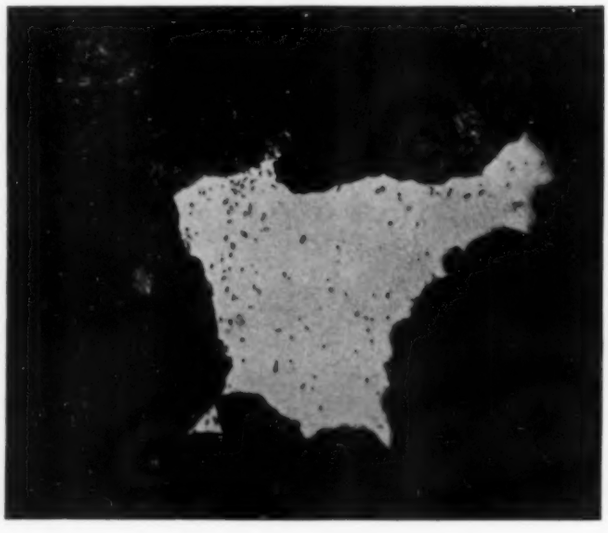
Dotted curves marked 900, 600 and 500 illustrate the course of the hardening cycle observed in the alloy after first water quenching from 1300° C. and then reheating at the given temperature in a salt bath for the plotted time. Resuming the lecturer's phraseology: "In this case we have forced the gamma-alpha transformation to take place at room temperature and then by reheating have allowed the precipitation of epsilon to proceed at a higher temperature within the fine-grained alpha matrix. This process goes on so rapidly at 900° C. (1650° F.) that after 10 sec. the alloy has increased in hardness from C-38 to C-64, but, as might be expected, it overages rapidly.

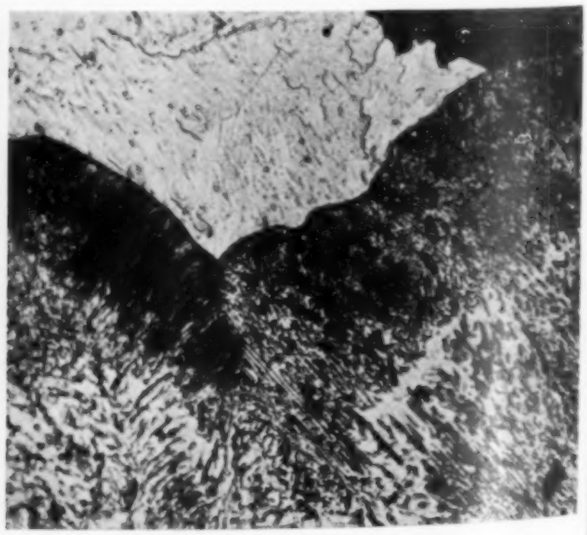
"Upon quenching from 1300° C. to 750° C. (1380° F.) the reaction begins with less delay than at 900° C. but moves more slowly to completion. As may be seen from the left micro on page 654, the product of gamma decomposition at 750° C. fails to display the lamellar appearance observed after the 900° C. reaction, but at 500 diameters assumes a needle-like or feathery form extending outward from a gamma grain boundary or from centers within the grain. At higher magnifications evidence of a lamellar nature is still visible."

At 600° C. (1110° F.) the alloy starts reacting only after 5 hr. has elapsed, although after 100 hr. it is approaching the high hardness of C-67 developed within an hour's aging of the water quenched alloy. "That by two such devious courses the hardness of a material should attain values substantially identical is in itself worthy of observation. More important, however, is the fact, demonstrated by the dotted



If the Alloy Is Quenched From 1300° C. Into Molten Salt at Subcritical Temperatures, the Gamma to Alpha Reaction Takes Some Time to "Incubate" and Then Proceeds to Completion at a Certain Rate. The S curve maps the data characteristic of each temperature. The decomposition product at 900° C. (1650° F.) — slightly below the transformation temperature — is a fast-etching material reminiscent of nodular pearlite; the analogy persists in its definitely lamellar structure shown in the micros below





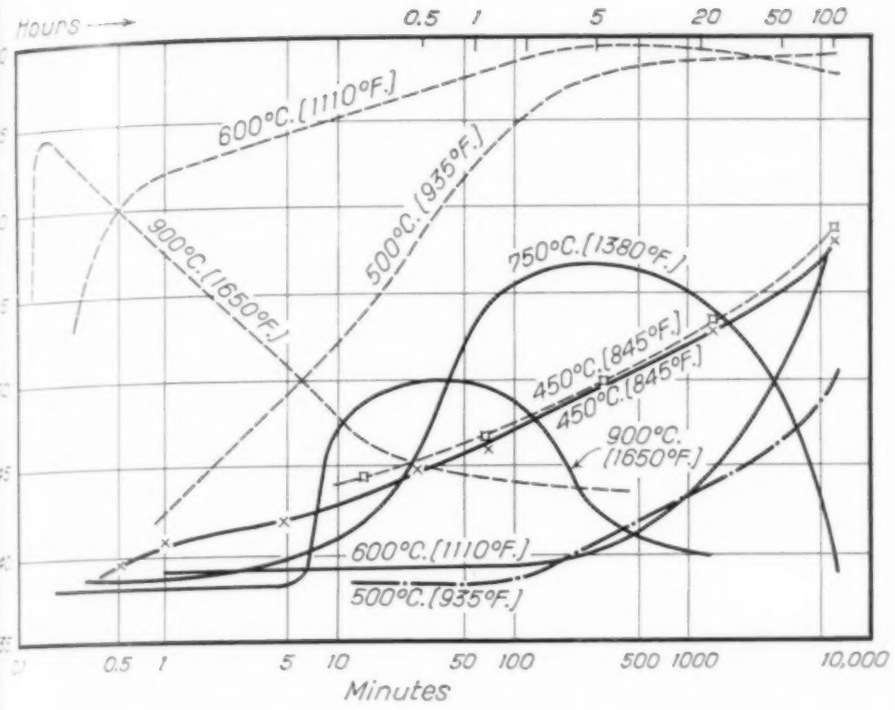


Diagram Showing Change in Hardness After Quenching From 1300° C. Into Salt Baths at Temperatures Shown on the Full Lines, Holding There for Times as Plotted Horizontally, and Then Quenching in Water. Dotted lines show change in samples water quenched direct from 1300° C. and then tempered increasing times at temperatures noted. The two curves for 450° C. superpose

curve for 600° C. in the diagram above, that in a fine-grained alpha matrix the precipitation and attendant hardening proceed at an extremely rapid rate when the alloy is reheated to 600° C. and has attained a maximum of Rockwell C-66 to 67 within an hour's time.

"The significance of this phenomenon will become apparent as we consider the progress of isothermal decomposition and hardening at temperatures below 600° C. If the alloy be quenched from 1300° C. to 550° C. (1020° F.) and held at the latter temperature, no measurable hardening is observed within the first 100 hr. This reluctance to harden is to be expected from the shape of the "S" curve.

"At 500° C. (935° F.) the formation of alpha is under way again at the end of an hour and in alloy specimens (water quenched from 500° C.) we find the presence of alpha revealed in these scattered areas of acicular pattern. See the right hand photomicrograph on page 654. These needles are outlined only by extended etching, and suggest in appearance the familiar martensite in a freshly quenched steel. Even though these needles at first etch with difficulty, they are shown to be substantially harder than the surrounding matrix by the microcharacter.

"With prolonged stay at 500° C. these areas multiply and some are darkened rapidly by the etchant, indicating the presence of a highly dispersed precipitate within the alpha needles. The microcharacter, in fact, shows that a remarkable hardness increase has occurred within the needles, the micro hardness number *K* having increased from 1830 to 6430 as the time at 500° C. is prolonged from 1 hr. to 50 hr. It appears, moreover, from the same test that hardening has also taken place in the matrix.

"The considerable increase in Rockwell C hardness which attends this precipitation at 500° C. within the newly formed alpha needles may be seen from the upswing of the full curve marked 500° C. in the diagram above. We have found earlier that a hardness of C-67 may be developed in the alloy by reheating at 600° C. for 1 hr. following a water quench from 1300° C. In such a case, precipitation occurs in a matrix consisting entirely of the fine-grained alpha solid solution formed from gamma during the water quench. A lightly etched microsection of the alloy fully hardened in this manner reveals the original Widmannstätten pattern (see the bottom photograph on page 651). If but a *part* of the gamma had transformed before the 600° C. reheating, we might expect rapid hardening only within those portions of the specimen occupied by the alpha phase, with a resultant hardness after 1 hr. at 600° C. somewhat below the C-67 value and bearing a close relation to the completeness of the gamma transformation."

A series of experiments wherein the sample was taken from one salt bath at 500° C. and immediately transferred to a hotter one at 600° C. confirms this prediction. After 1 hr. in the hotter bath, then quenching, the sample was hardened about 5 numbers on the C scale. This was true even of a sample held 30 min. at the lower temperature (on the flat portion of the

full curve, page 653). Obviously, the formation of alpha must have started during the first few minutes at 500° C.; otherwise the treatment at 600° C. would not have increased the hardness nor yielded the final structure — darkly etching needle-clusters in a background of alpha.

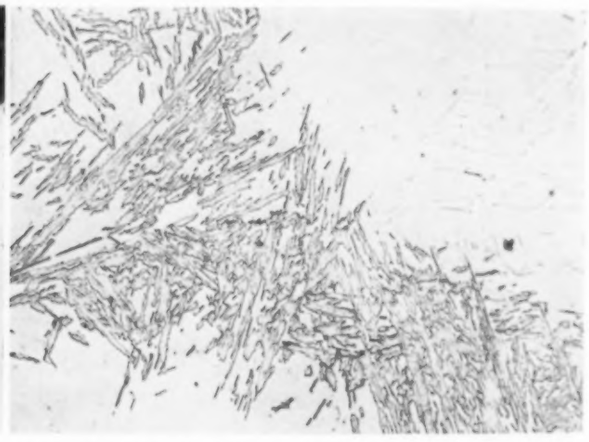
"Let us now consider the decomposition of gamma in a specimen at 450° C. (845° F.) following a quench to that temperature from 1300° C. Expansion begins almost immediately according to the dilatometric data and is substantially complete within 30 min. Hardness, marked with crosses on the diagram on page 653, also rises at a fairly uniform rate, reaching a value of C-58 after 100 hr. Superposed on this curve are the values marked with squares representing the 'normal' age hardening of this alloy at 450° C. following a water quench from 1300° C. From the coincidence of these hardness values we may conclude that in both cases precipitation of epsilon is taking place within a fine-grained alpha matrix. We should, then, anticipate with confidence the rapid development of full hardness if a specimen after 1 hr. at 450° C. were to be transferred directly to 600° C. and held at this temperature for 1 hr., and this, in fact, occurs, results being C-67 to C-68 after all stays at 450° C. of 1 min. to 100 hr.

"While no attempt was made to determine the transformation-time relationships at temperatures below 400° C. (750° F.) in this alloy, it is reasonably certain that in water quenching to room temperature the gamma is almost completely converted to alpha within a few seconds. Hardening data confirm this conclusion, for the maximum hardness is approached upon direct transfer to 600° C. following a 5-min. period at 200° C. No measurable hardening occurs at 200° C. within a period of 100 hr. and hence we must conclude that at this temperature the diffusion rate of tungsten is so low that precipitation of the epsilon constituent and the attendant hardening occur very slowly, if at all.

"Perhaps the most fascinating aspect is the analogy existing between these carbon-free ternary alloys and plain carbon steels.

"The microstructures resulting from gamma decomposition in the two alloys are remarkably similar. Precipitation of a carbide on the one hand and of a tungsten-rich compound on the other keeps pace with gamma-alpha transformation over limited ranges of decomposition temperatures. In the case of the steel this range extends down to 150 or 200° C. In the other alloy precipitation begins to lag at 500° C. (935° F.) and becomes infinitely slow at 300° C. (570° F.). The behavior of both alloys when first quenched from the gamma range to room temperature and then reheated is represented by time-hardness curves almost identical in shape. But to react thus the carbon-free alloy must be aged at 525 to 600° C. (1000° F.). This difference may reasonably be considered to result directly from the slower diffusion rate of tungsten in the alpha solid solution. As freshly quenched, both alloys exhibit the slow etching reaction typical of 'white martensite,' while the rapid darkening of the alpha needles by the etchant after aging indicates the presence of a highly dispersed precipitate."

Transformation at 750° C. (1380° F.) Assumes a Feathery Growth. Magnified 500 ×. It is of lamellar nature at higher magnification



Transformation Within 5 Hr. at 500° C. (930° F.) Gives White Martensitic Needles. (200 ×). Prolonged stay causes precipitation in the needles (they then etch rapidly)

ELECTRON DIFFRACTION

a new tool for research

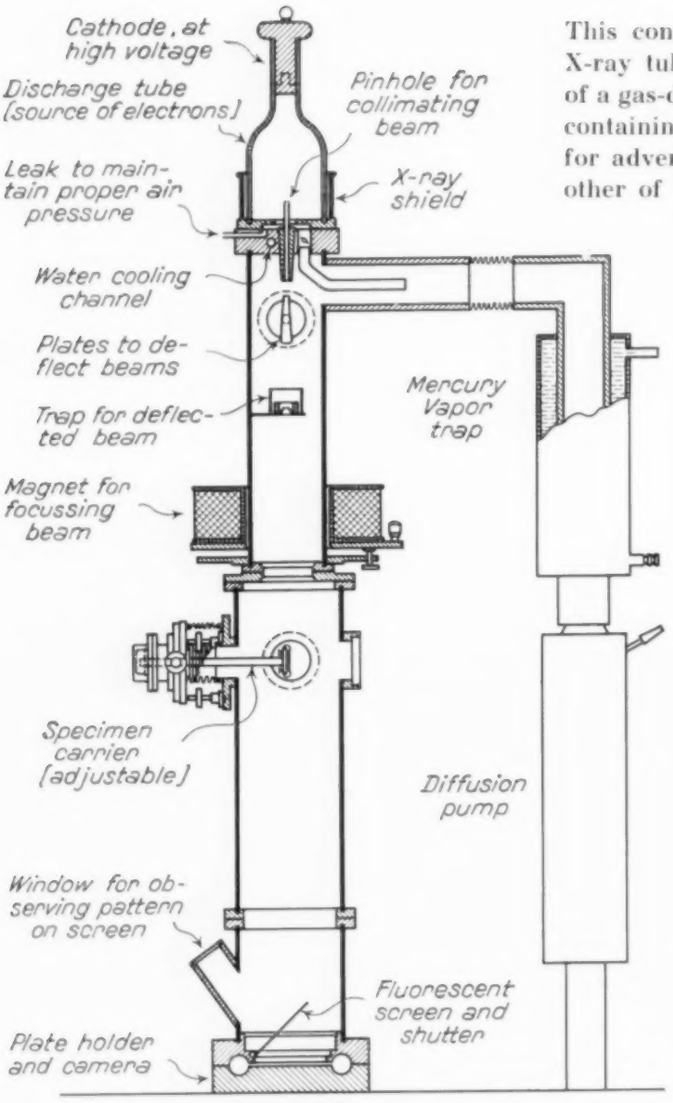
By C. S. Barrett
Metals Research Laboratory
and Department of Metallurgy
Carnegie Institute of Technology

IT WAS not many years ago that the diffraction of electrons by crystals was considered one more of those curious and somewhat useless phenomena in the realm of "pure" physics, confirming, to be sure, certain interesting theories of the nature and habits of electrons, but scarcely a thing of direct interest to the average metallurgist. Rapid developments in numerous laboratories here and abroad are changing this and are bringing electron diffraction into place beside other established research tools for physics, chemistry and metallurgy.

The development dates from 1927 when Clinton J. Davisson and L. H. Germer of the Bell Telephone Laboratories and, independently, G. P. Thomson in England first succeeded in getting a beam of electrons to diffract from a crystal in the way that a beam of X-rays does. The original discoverers have continued their investigations, and other laboratories have become active in the work, including three or four metallurgical laboratories in this country and perhaps more in England.

When a stream of electrons encounters a crystal it behaves in all respects like a train of waves: It is diffracted like a beam of light is diffracted by a grating of evenly spaced lines, or like X-rays are diffracted by the regularly spaced atoms of a crystalline substance. It is not necessary to insist that the electrons actually consist of waves, but they do go in those directions, on the average, that true waves of a certain wave-length would go. The electron wave-length — or, more precisely, the wave-length that accounts for the motion of the electrons — depends on the velocity with which the electrons are moving and is the shorter the greater this velocity. The electron velocity, in turn, is directly related to the voltage applied to the electrodes of the vacuum tube in which the electrons move. The relation giving the wave-length λ in terms of the voltage V applied to the tube is $\lambda = \sqrt{150 \div V}$ in Ångström units (an Ångström is 10^{-8} cm.). Since it is convenient to operate electron diffraction equipment at potentials between 30,000 and 70,000 volts, it follows that the electrons ordinarily used in diffraction work have a wave-length between a tenth and a twentieth of the wave-length of X-rays used for similar work.

It might be mentioned that all other material particles as well as electrons have this property of acting as if they were waves; physicists have succeeded in diffracting atoms and mole-



An Electron Diffraction Camera (Cambridge Instrument Company, Inc., After a Design by Finch)

cules from crystal surfaces, and if it were not for certain technical difficulties we might even be diffracting golf balls about the laboratory! The difficulties in experiments with particles heavier than electrons are considerable, however, and these experiments do not yield a proportionate amount of new information above that given by electron diffraction. The same can be said of experiments with slow electrons produced in apparatus operating at only a few hundred volts. Applications of interest to metallurgists have been made almost entirely with fast electrons in the range between 30,000 and 70,000 volts.

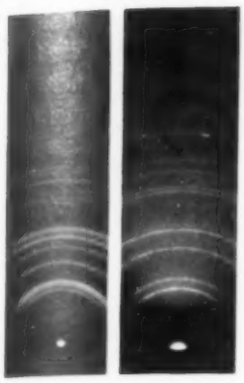
Essential parts of an electron diffraction camera are sketched in the figure shown above. A source of electrons is the first requirement. This consists of a hot filament of the type used in X-ray tubes, or in alternative designs it may consist of a gas-discharge tube similar in principle to the tubes containing rare gases that are now so commonly used for advertising signs. The electrons from one or the other of these sources are accelerated by an applied voltage, which is supplied by a constant potential, direct current, electrical machine, and are collimated into a fine stream by passing through small pinholes. The electron beam is then directed at the specimen, where it is either reflected from the surface or transmitted through the specimen, if thin enough.

Electrons in the beam, interacting with the atoms in the specimen, are diffracted or "reflected" by the atomic planes at definite angles that are determined by the crystalline structure of the specimen and the wave-length of the electrons. The diffracted beams are made visible by intercepting them with a screen of fluorescent material that emits light when the electrons impinge on it, and after adjustments have been completed a permanent record is made by exposing a photographic film to the diffracted beams. The pattern that appears on the film after it is developed is similar in most respects to the diffraction patterns produced by X-rays, the principal difference being that it is confined to a much narrower range of angles because of the shorter wave-length of the electrons.

All of these essential elements — the source, pinholes, specimen, fluorescent screen and film — must be mounted in a chamber that is highly evacuated, for the electrons would be rapidly absorbed in air at ordinary pressure. The necessary vacuum is maintained by pumps of the mercury diffusion type and their auxiliary equipment, and ingenious devices are used to manipulate the pinholes, specimen, and film from the outside of the vacuum chamber.

Studies of Thin Metallic Films

The most striking characteristics of the electron diffraction method are the extremely short exposure times required to produce a fully exposed photographic film — fractions of a second instead of the hours that are usual in X-ray work — and the minute quantity of matter that will diffract the electrons. A metallic film so thin as to be translucent or transparent to light



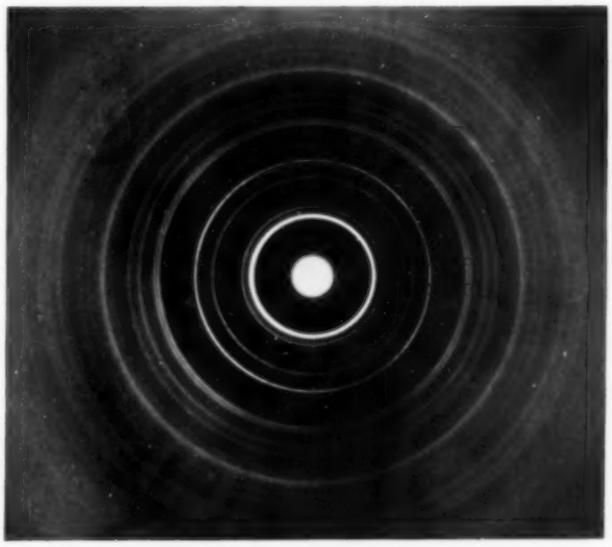
Electron Diffraction Patterns Formed by Reflection From Surface of a Specimen. On the left—zinc oxide; on the right—gamma phase of aluminum-zinc alloy (Courtesy M. L. Fuller, New Jersey Zinc Co.)

will diffract electrons very strongly and, in fact, if a film is much thicker than this it will completely absorb them; a layer of oxide on the surface of a metal will produce a diffraction pattern when it is thin enough to give interference colors (temper colors) or in some cases when it is so thin that it is invisible.

One of the most successful applications has therefore been the study of thin films of this sort including those produced by electrodeposition, sputtering, precipitation from colloidal suspension, condensation of metal vapors, oxidation and other chemical reactions at metal surfaces. In this field electron diffraction is able to provide the same kind of information that X-ray diffraction provides for thicker layers; namely, the identification of the phases in the layer and their crystal structures, the approximate grain size in the layer, the state of strain in the layer, and the orientation of the grains.

But the peculiar advantage of the use of electrons for work in this field lies in the fact that they are diffracted strongly by the very outermost atoms of the specimen and convey information to the photographic plate concerning these atoms only, whereas the X-rays pass through these surface atoms without being much affected and penetrate to much greater depths, thus recording, when they emerge, chiefly the conditions in the deeper layers. Electron diffraction deals with the outer millionth of an inch or so of the specimen and can detect, for example, the invisible oxide layer that forms on copper exposed to the air at room temperature for a few minutes. X-rays deal with layers whose thickness is measured in ten-thousandths or thousandths of an inch.

It is because of the extreme importance of thin films in the processes of oxidation and corrosion that metallurgists have followed the development of electron diffraction with such interest. They have at their hand, at last, a method of revealing and identifying the protective oxide layer that forms on aluminum, the passive film on iron, and the composition of the oxide layer on stainless steels and other corrosion resisting alloys. Accompanying illustrations show the type of patterns formed when electrons are reflected from the fine-grained material at the surface of a metallic specimen. The spacing, intensity, width, and smoothness

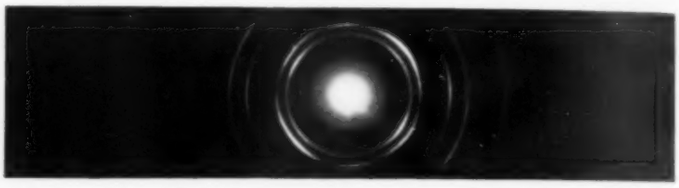


Left: Electron Beam Penetrating Film of Silver Four Millionths of an Inch Thick Gives a Beautiful Diffraction Pattern. (By L. H. Germer, Bell Telephone Laboratory)

Below: Single Crystals Give a Diffraction Pattern of Spots. This striking pattern was formed by transmission through a very thin single crystal of graphite (G. I. Finch, Imperial College of Science and Technology, London)

of the rings characterize the crystal structure, grain size, and orientation of the metal or oxide surface. Layers of non-metallic materials on the surface have been effectively studied by electron diffraction in connection with lubrication and wear problems; for example, oriented graphite layers are found on cast iron cylinder walls and piston rings, and oils and greases are found to adhere to the surface with their molecules oriented in definite directions.

The nature of the bond between oxide and metal is opened to investigation and the distorting effect of the metal on the first few layers of atoms in the oxide can be seen clearly. It has been found that the crystal structure of thin deposits in many cases is altered to match the arrangement of atoms on the surface of the substratum. Aluminum is distorted from a cubic structure into a tetragonal one when deposited in a thin layer on platinum, for example, and similarly, zinc oxide forms on zinc with the lattice of the oxide distorted to match the lattice of the metal. Anomalous lattice dimensions, such as these, exist over only a few layers of atoms adjacent to the metal-to-metal or metal-to-oxide interface and are not detected by X-ray investigations of thicker layers. Sometimes crystal structures of these oxide layers are entirely different from those observed for the same material in bulk; for instance, a new cubic modification of zinc oxide has been found adhering to zinc.



Pattern Formed by Transmission Through a Thin Gold Foil in Which the Grains Have a Preferred Orientation (M. L. Fuller)

Below: Reflection Pattern of Iron, Electrodeposited on Polished Copper, Shows Intense Arcs Due to a Preferred Orientation of the Grains (G. I. Finch, Imperial College of Science and Technology, London)

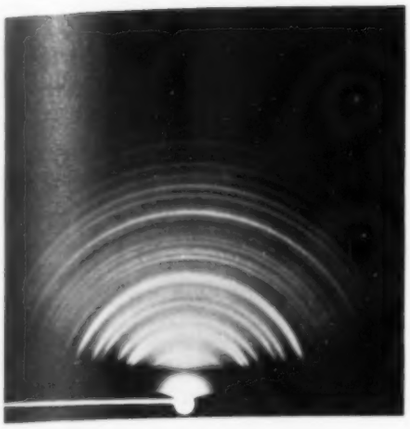
It is quite the usual thing for the thin deposits to have a preferred orientation of some sort. This is revealed in the patterns by a lack of uniformity in the intensity of exposure of each ring on the photographic plate, or, in certain cases, by abnormal intensities of certain rings, indicating a preference for certain planes in the crystal to lie parallel to the substratum, or for the crystal axes to point in certain directions. (Note the pattern just above from electrodeposited iron.) Thin, oriented layers on single crystals were discovered in the early electron experiments of G. P. Thomson; X-ray studies by R. F. Mehl and his coworkers have shown that thicker oxide layers on single crystals are oriented, and now it is known that a great many deposits on polycrystalline metals, and on mica and celluloid have a preferred orientation.

Thin deposits of metals on polished metal surfaces are not permanent. Finch, Quarrell and Roebuck have noticed that the diffraction pattern of the deposit is visible for a few minutes or a few hours, depending on the combination of metals used, but it gradually fades away, probably as a result of diffusion of the deposit into the substratum while standing at room temperature. A similar deposit on etched metal does not fade in this way, from which it appears that the rate of diffusion into the polished layer is much more rapid than into the undistorted metal. Quantitative information on diffusion rates may be anticipated.

Gases Absorbed in Metals

The extraordinary sensitivity of the electron diffraction camera to thin layers of material can be a considerable nuisance when it comes to actually carrying out an experiment. It is a standard complaint that almost anything, if given a chance, will collect on the specimen in sufficient quantities to cause trouble. The thinnest invisible deposits of grease, for example, give excellent diffraction patterns, as many investigators have found to their sorrow, and a little mercury deposited from the vapor that has worked back into the camera from the vacuum pump will quickly affect the patterns.

For this reason there has been much uncer-



Pattern Formed by Reflection From the Oxide on Ingot Iron After Heating to About 400° F. The rings indicate the hexagonal oxide, alpha Fe_2O_3. (H. R. Nelson, Battelle Mem. Inst.)

the resulting diffraction pattern consists merely of two very broad, diffuse rings. The striking diffuseness of the pattern is interpreted by many experimenters to indicate a lack of crystallinity in the surface material and to furnish direct proof of the amorphous metal hypothesis. At the 1935 symposium of the Faraday Society in London, devoted to the "Structure of Metallic Coatings, Films, and Surfaces," it became evident that this is the opinion of nearly every English investigator, and after reading the papers and discussion at this symposium it is difficult to believe that any grounds remain for doubting that polished surfaces are amorphous.

tainty as to the interpretation of certain peculiar rings that are occasionally found in the diffraction patterns. These "extra" rings, not found in the normal patterns, may be the result of surface contamination, but recent experiments by Finch and Quarrell seem to indicate that at least some should be attributed to absorbed gases, for they depend both on the nature of the metal and of the gas. It is reported in this connection that gold and silver foil will show extra rings after a mild heat treatment in air, and that the extra rings are removed by subsequent heating in a vacuum, as if oxygen were dissolved interstitially in the crystal lattice by the first heating and driven out by the second.

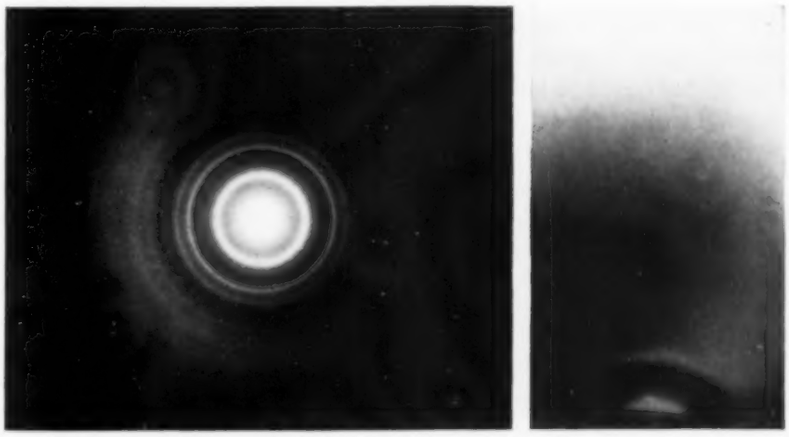
Amorphous (?) Metal

There has been — and perhaps will be — no end to the arguments about the nature of the polished surface of metals. The discussion centers around Sir George Beilby's suggestion, made early in the century, that the polishing operation distorts the crystals until all crystallinity is lost and the atoms at the very surface have only the haphazard arrangement characteristic of an amorphous material such as a supercooled liquid. This amorphous metal theory has had many ups and downs during its tempestuous life, but the principal "up" was given to it a few years ago in this manner:

When a beam of electrons falls with glancing incidence upon a polished metal surface

There are, however, certain very good reasons for questioning the value of this electron diffraction evidence. Dr. Germer, for instance, has shown by a number of ingenious experiments that the same pair of diffuse rings (so widely interpreted as proof of amorphous metal) can actually be produced from samples that have never been polished, as well as from samples with smoothly etched surfaces! In fact, both Germer in this country and Kirchner abroad have shown that a thin film of crystalline material may give a pattern of normal, sharp lines with a *transmitted* electron beam and yet show only diffuse rings with a *reflected* beam. A pair of Dr. Germer's patterns is reproduced at the bottom of this page.

This novel experiment is rather definite evidence that the crystalline nature of a surface cannot be judged safely by the results of a single technique. The explanation of this probably lies in the effect of slight surface unevenness upon



A Transparent Film of Zinc Sulphide, Eight Millionths of an Inch Thick, Gives a Crystalline Ring Pattern by the Transmission Method (on the Left) and an "Amorphous" Diffuse Pattern by the Reflection Method (on the Right). (L. H. Germer, Bell Telephone Laboratories)

the diffracted rays, for if the electrons enter and leave the *same* surface the direction of the diffracted rays that emerge will be altered by changes in the slope of the surface. Thus, if the surface is wavy, the diffracted rays will emerge in various directions and there will be a corresponding diffuseness in the diffraction pattern. On the other hand, if the beam enters and leaves *different* surfaces — or passes through thin projecting edges — this factor is not effective and a sharp pattern is possible.

While Dr. Germer thus discredits the testimony of the reflection experiments on this question, he does not insist that the Beilby amorphous metal hypothesis is necessarily wrong. In fact, it seems to be impossible to reach a definite conclusion on the question at this time, for some experiments point in one way and others point almost as clearly the other way, while the majority have been conducted in a way that prevents any rigorous conclusion to be drawn from them.

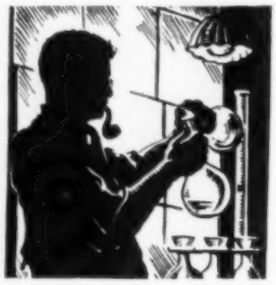
METAL CANS FOR FOOD

Massachusetts Institute of Technology recently conducted a "Food Technology Conference," at which Robert S. Williams, head of M.I.T's Department of Metallurgy, read a paper on "Research in Metallurgy and Its Significance in Canning." Herewith is a digest thereof, prepared by Myron Weiss, associate editor of Time Newsmagazine

RESEARCH in the canning industry, as in any industry in which metals are used, would presumably consist of:

1. A study of the properties of commonly used metals with a view to determining their good and bad qualities. As a corollary to this study would be added the development of tests for these properties, tests which are accurate, reproducible and as rapid as possible. Such tests require the most painstaking study as they may well become the basis for the selection or rejection of large quantities of material involving large sums of money. Research leading to the establishment of such tests may result, and indeed is known to have resulted in the past, in savings many times the cost of the investigation.

2. A second purpose of metallurgical research is in the development of new alloys for specific purposes. With more than five thousand different alloys available today it would seem as if there were no need for further research of this kind, but actually the number of possible combinations of metals is limitless, and alloys will surely be found that are more satisfactory for your needs than those now available.



3. A third object of metallurgical research closely associated with the first is the establishment of suitable standards for acceptance of metals and alloys purchased either for the manufacture of cans or to be used in kettles, trays, pans or other equipment of the canning industry. These standards may be physical or chemical but probably will be both.

The application of research to a special problem may be illustrated by a brief account of an investigation carried out at Massachusetts Institute of Technology in association with one of the can manufacturing companies.

A most serious situation had developed leading to an enormous number of failures due to corrosion inside the can with the corresponding formation of hydrogen. "Springers" and "swells" developed to an alarming degree. A most detailed investigation of the cause of these failures involving several million separate observations was carried on by the company. Studies were made of different varieties of fruit, soil conditions in different orchards, of differences in fertilizers and sprays, of differences in cooking methods.

Eventually a careful metallurgical study of the tin plate was

(Forward to page 692)

COLUMBIUM IN STEELS

plain chromium & chromium-nickel

By W. D. Wilkinson, Jr.
Electro Metallurgical Co.,
New York City

IN 1801 CHARLES HATCHETT found that certain hard, dull-black crystals which the British Museum had obtained from Haddam, Conn., possessed properties unlike those of any other mineral then known. Recognizing that he had discovered a new mineral, he named it columbite after Columbia, since the sample had come from America. A year later a similar mineral was found by A. G. Ekeberg, of Sweden, in a sample from Kimito, Finland, and subsequently by other scientists in specimens from Bodenmais, Bavaria, from Australia, and from numerous localities in North America.

Because of the similarity of columbite to the mineral tantalite, the geologist Wollaston in 1809 mistakenly proclaimed that columbium and tantalum were identical. About 1840, however, Rose definitely proved that columbium was a distinct element, and called it niobium (from Niobe, daughter of Tantalus) to distinguish it from tantalum. For a while, Rose believed that he had discovered still another element, pelopium, but in 1853 he concluded that niobic and pelopic acids were obtained merely from different oxides of what he called niobium. (Further information on the discovery and identification of columbium may be found in the *American Journal of Science and Arts*, 1877, p. 359, and *Proceedings* of the American Philosophical Society, 1905, p. 151.)

Columbite is now known to be an iron columbate in which iron and columbium are usually replaced in part by varying amounts of manganese and tantalum. If columbium predominates the mineral is called columbite; if tantalum predominates the name given is tantalite. These two elements are often associated with each other in varying proportions and with various amounts of iron. The Black Hills of South Dakota and parts of North Carolina, Colorado, and Greenland are among the sources of columbium in the Western Hemisphere.

The absence until recently of any substantial commercial use of columbium, and the fact that because of this it had not been made available in large amounts, have given the impression that columbium is an exceedingly rare element, but this is erroneous. The sources of columbite in the United States, Africa, Australia, and other countries are deemed adequate not only to satisfy present demands but also, as far as can be foreseen, to take care of any future demands for those applications in which its use has been shown to be beneficial.

This Typical Lump of Ferro-Columbium Contains Approximately 55% Columbium, 80 to 85% of Which Is Recovered When the Ferro-Alloy Is Used in Making Columbium-Bearing Steel

Columbium metal was first prepared by Blomstrand in 1866 by reducing the chloride with hydrogen. Twenty years later Marignac sought to reduce the complex columbium salt, potassium oxy-fluo-columbate, K_2CbOF_5, with aluminum, but his resulting product was an alloy of columbium and aluminum. Around 1900 Henri Moissan obtained metallic columbium by the reduction of its oxide with carbon in an electric furnace.

Separation of Metallic Columbium

According to Moissan's notes published in *Comptes Rendus* in 1901, he used an American columbite, first fusing it with carbon for a short period with a high amperage current. He states that by this method the columbium was freed from manganese, some of the iron, and most of the silicon. The result of this operation was an alloy of columbium and tantalum, together with some combined carbon. The columbium was next separated by chemical means from the tantalum. Being then in the form of an oxide, the columbium was again reduced with carbon in the electric furnace. The resulting product undoubtedly was high in carbon in the form of columbium carbide.

The method of obtaining metallic columbium that a producer of this metal uses at present is to dissolve the oxides of columbium and tantalum in hydrofluoric acid and then to convert to the double fluorides with potassium. The two compounds can then be separated because of their differences in solubility, and the columbium then obtained by electrodeposition from its fused salt.

For the most important commercial uses columbium does not need to be completely isolated and it is therefore used in the form of a low carbon ferro-alloy containing from 50 to 60% columbium. Ferro-columbium is an electric furnace product made by methods analogous to those used in the commercial production of similar alloys.

Columbium is a malleable steel-gray metal with about the hardness of wrought iron and with a specific gravity of 8.57. It can be spot welded to itself or to other metals, and in the absence of oxygen fine particles can be sintered together under pressure while hot. Moissan was the first to note the unusual ability of molten columbium to absorb and combine with carbon. From a metallurgical standpoint, this property of columbium is most significant and important.

Although columbium has been used as the cathode in electrolytic rectifiers of alternating current, and in radio tubes both as an oxygen "getter" and as a filament, there are no very important uses of the metal in its pure form. Similar conditions exist abroad, in the opinion of contributors to the 1930 edition of The Mineral Industry of the British Empire and Foreign Countries. However, its properties suggested that columbium might be valuable as an alloying element in steel.

Some early work on this application indicated that columbium has an even greater toughening and hardening influence on steel than elements such as vanadium, tungsten, chromium, and molybdenum. It was even suggested that in a high speed steel 6 to 12% columbium might replace 12 to 20% tungsten. The addition of about 2% columbium was recommended for steels containing certain amounts of tantalum and tungsten. Columbium was also observed to have a scavenging action.

Although these results and proposed applications were described as early as 1920, they were apparently of more theoretical than practical interest, and high columbium steels were

never used to any extent. The hardening and toughening effects and the scavenging action apparently could be attained more economically through the use of ferro-alloys of other metals.

An important contribution to the literature on columbium as an alloying element in steel appeared in 1933, when Becket and Franks discussed before the American Institute of Mining and Metallurgical Engineers the effects of columbium in plain, high chromium steels. Plain chromium steels had been used for many years because of their strength, hardness, and corrosion resistance, and one of their well-known properties is a tendency on air cooling to develop a martensitic structure, which is relatively hard and brittle.

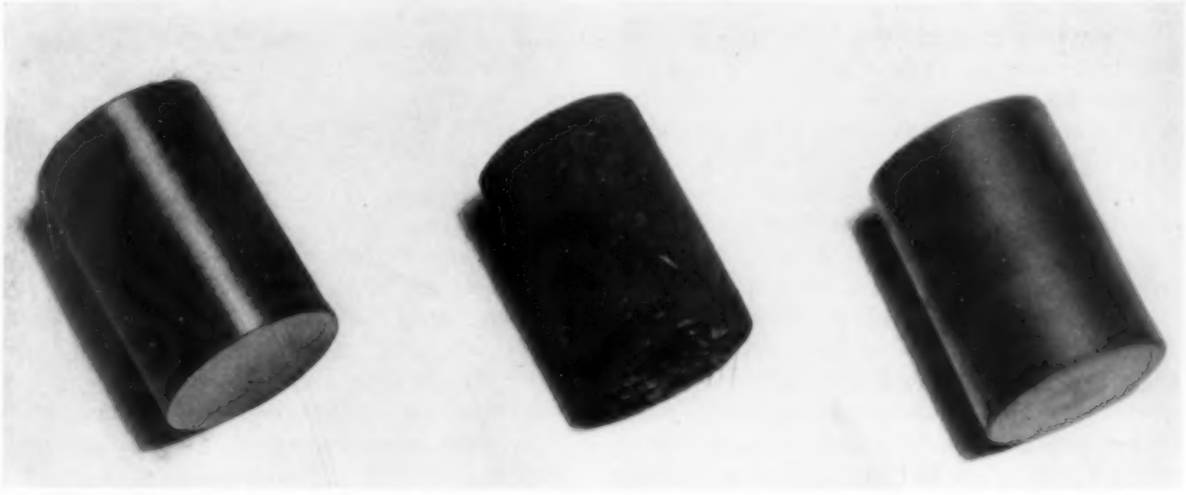
Knowing that the character of a steel is governed largely by the iron-carbon constituent and that columbium, having a strong affinity for carbon, forms stable carbides, Becket and Franks decided that the effects of columbium in chromium steels of the air hardening type would be worthy of investigation. Easier control of air hardening would be an advantage in the production and fabrication of these steels. It was discovered that columbium modifies the carbon constituent of these chromium steels in such a way that their tendency to air harden is largely overcome. Consequently, even thin gages remain soft and the steels are more suitable for hot working. Its effect on the Rockwell hardness of welded joints in 4 to 6% chromium steel is as shown in the following tabulation:

	Plain Chromium Steel	Columbium-Bearing Steel
Base metal	B-75, 76	B-76, 77
Near weld	B-80	B-77
Contact zone	B-110	B-85
Weld	B-87, 85	B-87, 87
Contact zone	B-111	B-83
Near weld	B-85	B-77
Base metal	B-76, 75	B-76, 76

Practically no hardening can be detected in the base metal. Welding rod in this experiment contained 24% chromium, 12% nickel.

Another significant effect noticed in high chromium steels is that columbium shortens the annealing period required to improve their properties, particularly their ductility. Even without annealing, columbium-bearing steels are often more ductile than plain chromium steels that have been annealed. Since there is not so much need for annealing to improve ductility, the presence of columbium in these steels insures better results when welding, or when cutting them with the oxy-acetylene flame. Latest data on the low chromium steels are contained in Russell Franks' paper before the convention, last month.

The results of Becket and Franks' investigation further indicated that the addition of columbium to steels containing less than 12% chromium improves their resistance to oxidation and to many corrosive agents. The improvement in oxidation resistance is retained at elevated temperatures. These effects are attrib-



These Specimens Show the Effect of Columbium in Increasing the Oxidation Resistance of Plain 6% Chromium Steels. At left is original size of sample; middle is plain 6% chromium steel after 600 hr. at 1380° F.; at right is 6% chromium steel containing 0.70% columbium after a similar treatment. The plain chromium specimen contained 0.06% carbon, the columbium-bearing specimen, 0.07% carbon

Engine Exhausts Carrying Hot Combustion Gases From Doped Gasoline Ha... Troublesome to Maintain, but the Ones Made of Columbium-Bearing Stainless ... United Air Line Transports Have Given Perfect Service Over a Long Period ...

uted in part to the fact that carbon combines more readily with columbium than with chromium. As a result, the formation of chromium carbides at elevated temperatures is largely prevented, and the chromium remains available in a form that will help the metal resist the attacks of corroding media.

Becket and Franks have also experimented over a number of years on the effect of columbium on the chromium-nickel austenitic stainless steels, and this work is reported in *Transactions* A.I.M.E. for 1934, page 143.

They were especially interested in the corrosion resistance of these steels after exposure to such temperatures as might be encountered in use or during fabrication.

Metallurgists will recall that ordinary stainless steels of this type are highly resistant to most corrosive conditions, but that those with ordinary amounts of carbon lose some of this resistance after being subjected to certain temperature ranges between approximately 750° F. (400° C.) and 1650° F. (900° C.), although the range in any particular case is generally much narrower. Subsequent exposure to corrosive media even at normal temperatures might then result in corrosion at or around the grain boundaries. Susceptibility to this type of corrosion is caused by subjection to the above temperatures during use, or sometimes by the heat of welding.

Although the corrosion resistance of the welded metal can be restored by heating to about 2100° F. (1150° C.) and then quenching, such heat treatment is not always practicable with welded installations. In such cases another method of eliminating any possibility of the metal being susceptible to intergranular corrosion would evidently be helpful. It is for this reason that experiments were made to determine whether the addition of columbium, which proved useful in stabilizing the carbon in plain chromium steels, would also improve the chromium-nickel austenitic stainless steels.

While it is not the intention of this article to outline the research work done on the effect of columbium in stainless steels, one series of tests will be mentioned because it is typical of the care and thoroughness with which the experiments were carried out. Becket and Franks decided to subject columbium-bearing stainless steels to various temperatures that might conceivably cause susceptibility to intergranular corrosion, and then compare their corrosion resistance with similarly treated control specimens that were free from columbium. Although the temperature range that causes subsequent disintegration on boiling plain stainless steel in corrosive media was found ordinarily to lie well within the temperatures given above, the test temperatures chosen ranged down to 570° F. (300° C.) to give greater latitude for exceptional cases. The corrosive agents for the tests were chosen on account of their general use in industry and their known aggressiveness. For this series of tests they were either a 65% solution of nitric acid (sp. gr. 1.4), or a 10% sulphuric acid solution (sp. gr. 1.07) with 6% copper sulphate. The samples were maintained at a specified temperature for periods varying from 1 hour to five months, and then boiled for at least 200 hr. in the corrosive test solution.

The results of these tests indicate that columbium-containing austenitic chromium-nickel steels have excellent resistance to intergranular corrosion after having been exposed for long periods of time to temperatures ranging from 570° F. to 1650° F. (300° C. to 900° C.). They were found to be fully corrosion resistant under many conditions that cause severe attack on the plain chromium-nickel steels. After

welding they are quite as resistant as before.

Here again the affinity of columbium for carbon explains in large measure the advantageous influence of columbium in stainless steel. Various other alloying elements were investigated and tried as a stabilizing agent in stainless steel, but none has been found more satisfactory.

The amount of columbium necessary in 18% chromium, 8% nickel stainless steel depends on the carbon content of the steel; with a given carbon content, it depends upon the service for which the steel is intended. If the steel, in service, is exposed to temperatures of less than 570° F. the columbium content of the finished steel should be at least six times the carbon content. If the steel is to be subjected to higher temperatures the columbium content should be ten times the carbon content. With these amounts in the steel and welding rod it is unnecessary to reheat and quench fabricated structures after welding in order to obtain freedom from intergranular corrosion.

One of the early commercial uses of columbium was in welding rod. It is particularly valuable for this use because there is little loss of columbium in the deposited weld metal. The use of columbium-bearing stainless steel as a base metal for welding recently has become important commercially.

Considerable equipment is being constructed of columbium-bearing plate welded with columbium-bearing welding rod. Evidence of the satisfaction afforded by such equipment is the fact that the American Society for Testing Materials now includes columbium-bearing chromium-nickel austenitic steels in its specifications.

Columbium is so beneficial in the steels investigated that additions of columbium to other grades of steel would likewise be expected to impart desirable properties. This expectation is confirmed by laboratory tests on both low alloy and carbon steels containing columbium.

The method of adding columbium to steel is similar to that used in adding other readily oxidizable alloys. In order to keep the loss as low as possible, ferro-columbium should be added to the steel bath after it has been thoroughly deoxidized and as short a time as possible before it is poured. Time enough should, however, be allowed for the ferro-columbium to dissolve completely in the steel. With good furnace practice a recovery of 80 to 85% of the columbium is obtained.

ELECTRIC FURNACES
in the Foundry
Advantages & Disadvantages

RICHARD SCHNEIDEWIND of the Department of Engineering Research, University of Michigan, decries the use of such terms as "cupola iron," "electric furnace iron" or "air furnace iron" in trade and promotional literature, since the furnace is only a means to an end in the hands of competent men. It, with other features of foundry practice — such as charge, melting practice, sand control, molding art — all contribute to a good or bad product.

In a discussion at the Fall Technical Conference of the American Foundrymen's Association at Columbus, Ohio, he cited several advantages of the electric furnace for the production of cast iron. First and foremost is its versatility, the ability to produce widely different analyses at will in successive heats. Next, close chemical control of the product is possible, given the necessary skill in operation. Temperatures are also under control, and can be varied, heat to heat, depending on the nature of the metal and the castings to be made, running up to any degree of superheat, limited only by the refractory lining and roof. As compared with the cupola, it is a handier producer of low carbon, high strength gray irons. Lastly, given the necessary refining technique, lower grade scrap can be used, whenever refining costs are less than the price differential for high grade melting stock.

Certain disadvantages counteract, in part, these advantages over the cupola. Primarily, the melting costs are usually higher, principally due to expensive electric power, refractories, and capital charges on equipment; this may sometimes be reduced by duplexing with the cupola. Next, the size is ordinarily limited to about 4-ton heats in indirect arc furnaces. Direct arc furnaces are made with larger capacities. A dearth of good melters is so evident that the builders are importuned to "sell" a competent operator with each furnace! A metallurgical disadvantage is that the melting conditions are oxidizing, whereas a properly operated cupola is reducing; the former can, of course, be turned to an advantage when refining an inferior charge.

A MAN OF METALS

Blackstone Studio, N. Y.

George Booker Waterhouse

The new President of American Society for Metals came to America in 1903, recipient of one of the "1851 Exhibition Scholarships," and studied nickel steels under Howe and Stoughton at Columbia. For 18 years with Lackawanna Steel Corp., becoming Chief Metallurgist and Inspector, he resigned in 1922 to become Professor of Metallurgy at Massachusetts Institute of Technology

AMERICANS have become hardened to the jibes of European friends that their fetish is "bigness." Possibly this idea is nourished by the somewhat standardized route of the sight-seeing foreigner: New York to Niagara Falls to Atlantic City to New York. At any rate, we can counter our English cousins with a polite retort about their pride in the Crystal Palace, the biggest thing of its kind that ever was or would be. Or at least we *could*, before it caught on fire a year ago, and what a great fire that was, with a glare to be seen 50 miles away! The Crystal Palace was huge, never to be forgotten, even to the last.

The palace, as remembered by the million visitors who saw it annually, was somewhat larger than originally designed by Joseph Paxton and built for the 1851 Exhibition. Even then its ground plan covered 18 acres, and the balconies five more, enough for the booths of 17,000 exhibitors. In 1854 it was moved, piece by piece, from Hyde Park to Sydenham. A building of cathedral plan and dimensions, built of glass over a cast iron and wrought iron skeleton, it violated so many concepts of architectural integrity, centuries old, that only the vigorous personal championship of Prince Albert permitted the work to proceed.

These old Englishmen pointed the way in more ways than architectural. The "Exhibition of the Industry of All Nations" was sponsored by the Society of Arts, of which the Prince Consort was president, opened promptly on date, showed for a year to about six million persons, and closed with a neat profit of £119,036 18s 6d. (No second opening to clear up an accumulated debt!) They also knew what to do with the profit, for it was well invested and the interest finances the "1851 Exhibition Scholarships," even more highly valued than the Rhodes Scholarships, for they enable the recipient to pursue advanced study in any country or institution he chooses.

Among the 1851 Exhibition Scholars who have come to America and who fortunately for us liked us so well they stayed, are Matthew A. Hunter, electrochemist and metallurgist, once of New Zealand but now of Rensselaer Polytechnic Institute, John Johnston the Scot, now director of research for United States Steel Corp., and George Booker Waterhouse, graduate student and prize scholar of Sheffield Technical College, England.

Three notable opportunities then opened up for young Waterhouse. Should he study under Howe at Columbia, Ledebur at Freiberg, or Stansfield at McGill? Son of a Sheffield clergyman, he had got the smell of the famous steel plants in his nose. J. O. Arnold, the teacher of Sheffield metallurgists, also had much to do with it. This pugnacious Irishman battled long and hard for a second carbide of iron, which he supposed to contain much less carbon than cementite, and to be responsible for some of the hardening reactions and structural characteristics of steel. Eventually, this idea was thrown out, along with beta iron, but not before Arnold's opponents had fought many bitter engagements. The inspiring example of a teacher valiantly battling for what he thought was right has stiffened Waterhouse's resolution innumerable times in later years.

How well he was regarded by the College authorities is, of course, implicit in the fact that he received the coveted scholarship; further proof is that his graduation thesis on "The Influence of Sulphur and Manganese in Steel" was published in the Journal of the Iron & Steel Institute under joint authorship with Arnold. Likewise the University of Sheffield — of which the Sheffield Technical College was a part — has recently conferred on him the degree of Doctor of Metallurgy.

Electing to come to America in 1903 to pursue his graduate studies, young Waterhouse found that Henry Marion Howe was temporarily abroad. Bradley Stoughton was acting head of the Department of Metallurgy at Columbia University. Also studying or teaching there were the late William Campbell, the metallographist who succeeded Howe and Stoughton, and John F. Thompson, now executive vice-president, International Nickel Co. This was good company! Stoughton writes:

"Waterhouse's research was on the nickel steels, and was sponsored by Albert Ladd Colby for the International Nickel Co. and Bethlehem Steel Co., and John A. Mathews for the Crucible

Steel Co. Alloy steels were little understood then, yet nickel steel already had important applications for armor plate and heavy forgings, and was being considered for main members for the very large Blackwell's Island bridge, then being designed as a link between Manhattan and Brooklyn. He was the first to show that nickel dissolves predominantly in the ferrite instead of in the cementite. This has, of course, been one of the important observations which have helped to explain the nature and behavior of the nickel steels, especially the outstanding usefulness of nickel in toughening the core of carburized steels and in improving the fatigue resistance and impact resistance of other mild steels."

The first summer's vacation (1904) found Waterhouse at work for $60 a month at Lackawanna Steel Corp. near Buffalo, just building and taking over the business of the Scranton plant, shut down with the exhaustion of the Pennsylvania ore deposits. Evidently he made a good impression with the men higher up, for early in January 1905 they prevailed on Dr. Howe to release him from attendance at Columbia so he could come to them as metallurgist. His studies continued, however, and in 1907 he received the coveted Ph.D. In Lackawanna he made the friendship of Harry J. Kelley, a mechanical engineer at the steel works, and together they grew with the plant and became respectively chief metallurgist and inspector, and general superintendent of mills. Eighteen years of labor there may best be summarized in Kelley's words:

"One of Waterhouse's many accomplishments was the development and perfection of the duplex steel process, which was one of the outstanding achievements of its time. The Lackawanna plant was primarily a bessemer steel plant and during Dr. Waterhouse's regime, the process of steel manufacture was changed almost entirely from the bessemer to the open-hearth process, in which he also played a very important part. Among the Doctor's many qualifications was his ability to handle and direct men, and aside from his vast technical knowledge, he was especially capable of going into the various departments to direct the operation of steel manufacture." The cordial association of these two men still continues on the directorate of Dominion Steel & Coal Corp., Ltd., of Canada.

In 1922 came an opportunity for greater usefulness. Massachusetts Institute of Technology offered him the chair of metallurgy, and this was accepted. Always interested in affairs of the mind, Waterhouse influenced largely the growth of the metallurgical department until now it has become divorced from mining and stands solidly on its own feet. A notable staff comprises the faculty, and here again Waterhouse is within a charmed circle of such men as Williams, Hayward, Fay, Homerberg, Norton, Zavarine, Chipman. As one father of a recent graduate puts it:

"I began to hear more and more quite favorable comments concerning Professor Waterhouse's intimate and helpful attitude toward his student group, and in the end I was largely influenced by these reports in recommending to my son that he consider Massachusetts Institute of Technology as *the* school for him to enter in his pursuit of fundamentals and of metallurgical studies. This he has done, graduating just about a year ago and substantiating by his experiences, as well as his comments to me, all of the good things that we had heard about George Waterhouse and his most pleasant and understanding, yet effective, methods of teaching and advising his students."

Obviously, such a man as this is eminently fitted to lead the affairs of the American Society for Metals as president. A few more personal words are also in order: Shortly after going to Lackawanna George Waterhouse met and married Eleanor Frances Wood, a happy union clouded only by long invalidism. His wife died childless, late in 1935. Her husband's interest in young people and his public spirit manifests itself in civic activities in his home town of Belmont, Mass. For years he has been a member of the School Board, and is currently its chairman. With all these duties he still finds time to be a very active chairman and director of the Alloys of Iron Research (and Frank Sisco, its editor).

"His work as consultant and metallurgical expert has been most effective. In this field the sureness of his knowledge and ability to give a positive statement which could not be misunderstood nor misconstrued carry conviction to all who hear. Common sense is a quality which, contrary to the implication of the words, is rare indeed. Dr. Waterhouse has demonstrated many times that he possesses that uncommon attribute to a high degree," one of his clients writes.

And if any youngster needs to be disillusioned, let him take on George Waterhouse at squash rackets!

WORK SENSITIVITY

embrittlement by cold work

By S. L. Case
Metallurgist
Research and Development Division
Jones & Laughlin Steel Corp.

IN A PAPER presented in 1932 before the American Iron and Steel Institute, H. W. Graham introduced the term "work sensitivity," defining it as "the intensity of the reaction of steel to cold work." Evidence was submitted indicating that work sensitivity may serve as a useful measure of steel quality. The present paper gives in greater detail a method of evaluating work sensitivity. A subsequent one will submit additional evidence associating work sensitivity with aging characteristics of steel by measuring the progress of aging through its effect on damping capacity.

Conventional Tests for Metal Quality

The generally accepted standards governing the application of steel for its manifold uses are chemical specifications, physical tests, and metallographic observations. These standards are usually based on a previous background and often on *a priori* reasoning.

Chemical specifications are a useful guide, but they have certain inherent limitations. Their greatest weakness may be attributed to the fact that a chemical analysis furnishes no clue to the form or mode of occurrence of the ingredients; obviously, elements or compounds present in a state of solid solution in the ferrite exercise an influence on quality different in kind and degree from the effect of those present as visible extraneous inclusions or others existing in submicroscopic dispersion.

Metallographic observations also have recognized points of weakness. Such observations deal either with grain size or with non-metallic inclusions. The limitations of grain size observations will be considered later. Observations of non-metallic inclusions do not take into consideration the fact that the range of microscopically visible inclusions is a comparatively narrow band in the total range of particle size which may be present in the steel. No background for estimating the relative importance of visible and invisible inclusions exists, but there is undoubtedly a numerical preponderance of the invisible ones. Furthermore there is no accepted mode of interpretation. Some metallurgists associate visible non-metallic inclusions with inferior service performance. Other investigators speak of "beneficial dispersion of inclusions," making an exception for pathological cases of segregation such as "streaks" or "bands" of inclusions. Where such a difference of opinion exists, there is room for the thought that the invisible inclusions conceivably play an important part in the general picture of steel quality.

Physical tests generally measure a definite and distinct property of the material. As such, they therefore offer a reliable guide to an intelligent application, provided they are correctly interpreted and correlated with service conditions. This is a very serious limitation, which often leads to conditions impossible to fulfill.

It is almost self-evident, for instance, that a maximum figure for strength and fatigue endurance are irreconcilable with a maximum ductility and toughness. A compromise has to be effected, and here an error of judgment can be readily made.

Another very important limitation of physical specifications may be attributed to the fact that properties of steel, while often represented graphically on a two dimensional system of coordinates, in reality require a third dimension—time. The change in physical properties in the course of time is termed "aging." The capacity of the material for aging, and the rate at which aging proceeds, vary within wide limits in steels of identical analysis of common elements. Aging is apparently a phenomenon involving solubility changes and structural rearrangement, and is an indication of a metastable condition. The study of aging is beyond the field of microscope and test tubes and its progress can only be detected by its effect on physical properties.

It is a fallacy to assume that a non-aging steel is the final answer to the steel user's problems, because aging effects are sometimes highly beneficial to service performance. The correct evaluation of this property should be one of the essential requirements of a yardstick measuring steel quality. Such a viewpoint was advanced by Mr. Graham in earlier publications when he pointed out the marked difference in the intensity with which steels of apparently similar analyses will react to cold work.

Under the influence of cold work the static and dynamic properties of steel undergo a considerable change. The hardness, tensile strength, and yield point are raised, while the elongation and reduction of area are generally lowered. The dynamic properties such as impact toughness are influenced to a much greater extent than the static properties.

In most fabricating operations cold work in one form or another is involved. The resulting change in the impact properties of steel due to cold work deserves, therefore, very serious consideration if troubles in certain services are to be avoided.

In comparing the reaction to cold work of a number of steels of similar chemical analyses, it was found that the change in impact toughness, due to cold work, exhibits a greater range of variation than the other physical properties of steel. The tabulation below illustrates this point. The change in the static properties, caused by 2.2% reduction by cold work, is roughly of the same order of magnitude for both steels. However, the change in impact toughness is from 69 to 67 ft-lb. or 3% for Steel A-9, and from 86 to 8 ft-lb. or 91% for Steel A-3. Both steels are almost identical in their chemical analyses of common elements as shown in the second table. The "unstressed" samples were normalized at 1650° F. before testing; the "cold worked" samples were normalized at 1650° F. before cold working.

Since steels of apparently similar chemical composition often exhibit such marked differences in the extent to which their impact toughness is affected by cold work, it is quite apparent that an impact test offers a useful means of measuring the reaction of steel to cold work.

Analysis of Steels Tested

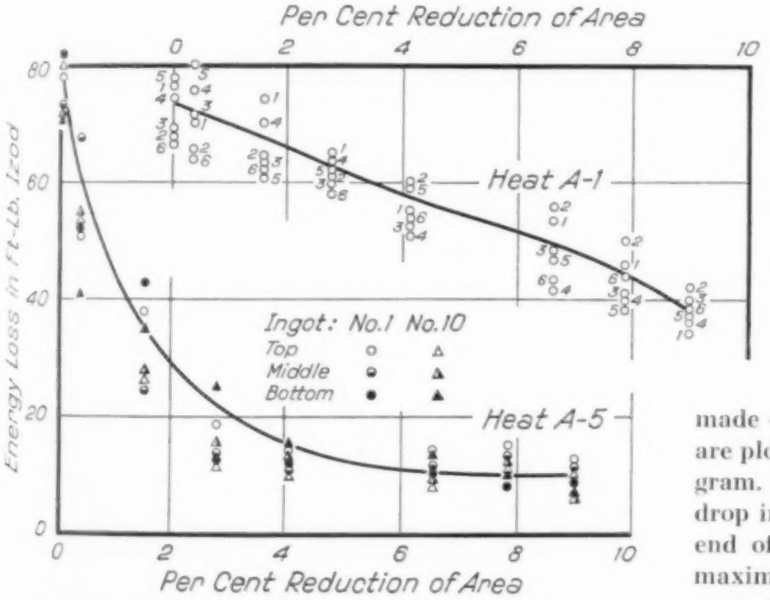
Mark	C	Mn	P	S
A-1	0.20	0.39	0.014	0.033
A-2	0.20	0.36	0.016	0.029
A-3	0.22	0.35	0.016	0.031
A-4	0.21	0.37	0.012	0.033
A-5	0.17	0.90	0.017	0.021
A-9	0.20	0.34	0.015	0.035
B-2	0.38	0.85	0.018	0.027
B-4	0.39	0.83	0.020	0.025
C-1	0.62	1.14	0.027	0.033
C-2	0.63	1.17	0.024	0.030
C-3	0.61	1.12	0.026	0.032

Effect of Cold Work on Properties of Two Steels

Mark	Condition	Static Properties				Dynamic
		Tensile Strength	Yield Point	Elongation in 2 In.	Reduction of Area	Izod Ft-Lb.
A-3	Unstressed	62,260	42,040	36.5	65.6	86
	Cold worked 2.2%	64,750	49,250	36.0	64.1	8
A-9	Unstressed	62,200	40,440	37.5	65.6	69
	Cold worked 2.2%	63,540	48,520	34.5	65.5	67

However, the preparation of a number of Izod or Charpy specimens, cold worked to varying degrees, is a laborious job.

A standard test for work brittleness was therefore developed. A test specimen is prepared consisting of a tapered round bar, 0.450 in. on one end and 0.475 in. on the other. The total length of the tapered portion is 10 in., and a 2½-in. prolongation 0.437 in. diameter is provided at the small end whereby it may be drawn through a 0.450-in. die. The result is a gradual increment of cold work from zero on one end to 10.3% reduction of area on the other end. The exact amount of cold work at any point of the drawn specimen can be easily computed, and is proportional to the distance from the original small end of the taper. The cold drawn specimen is then notched with an Izod Vee-notch at



Six Specimens From One Long Bar From Heat A-1 Give Concordant Results on Test for Work Brittleness. Bottom curve also shows that specimens from various billets from Heat A-5 all are badly embrittled by 4% reduction and more

1.1-in. spacings, and broken on an Izod impact machine, thus furnishing eight points for a complete "work brittleness curve" from one test specimen, the increment of cold work from notch to notch being equivalent to 1.2% reduction of area.

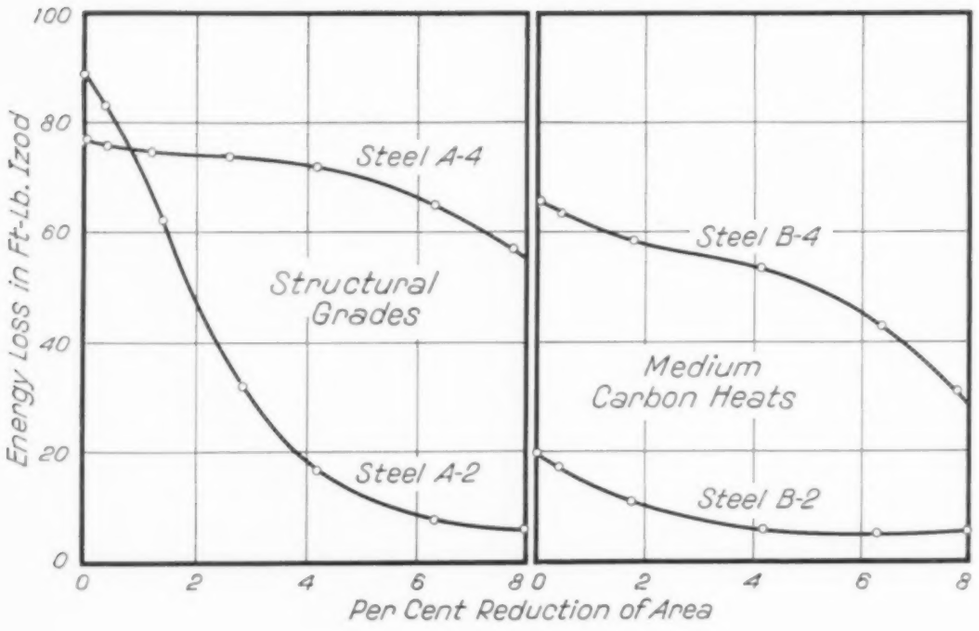
The flexibility of this type of test piece permits evaluating the effects of any desired increment of cold work. For instance, if instead of a 0.025-in. taper in a 10-in. length, a taper of only 0.005 in. be used, the cold work on such a specimen will range from zero on one end to 2.2% reduction of area on the other end, and the increment of cold work from notch to notch will be equivalent to only 0.27% reduction of area. When a taper of 0.050 in. is used, the maximum cold work on the big end is 19.0% reduction of area, and the increment of cold work from notch to notch is 2.4% reduction of area. These tapered test specimens are generally normalized previous to machining to eliminate any internal stresses which may be present.

In our practice the results of the test are plotted, using the energy loss as ordinate and per cent reduction of area as abscissa. The slope and general level of the resulting curve serves as a measure of the reaction of steel to cold work. When the slope is sharp and the general level low, the steel is termed "sensitive"; a slight and gradual slope and high average level denotes an "insensitive" steel.

A quality test on steel is not entitled to serious consideration unless it fulfills two essential requirements: First, it must check reasonably well with duplicate tests on the same bar, and second, it must show comparable results on tests taken from the same heat. The test for work brittleness apparently fulfills both requirements.

Results of six such tests made on one bar of steel from Heat A-1 are plotted in the top part of the first diagram. All of these tests show a gradual drop in Izod values from the unstrained end of the test to the end receiving a maximum of cold work. The total drop averages about 35 ft-lb., and the drop from notch to notch is of the same order of magnitude on all tests. The gradual loss of impact toughness with progressive cold work classifies this particular heat of steel as "insensitive."

A typical "sensitive" steel is shown by results plotted in the lower part of the same diagram. These were selected bars from top, middle, and bottom billets of the first and tenth ingot from Heat A-5, and point to the conclusion that definite sensitivity characteristics are a fixed property of the entire heat, since on all billets a sharp reduction in impact toughness occurs between zero and 2.8% reduction of area, and the total drop in Izod from zero to 9% reduction of area is about the same on all tests.



Steels of the Same Grade and Same Chemical Analysis May Have Markedly Different Susceptibility to Brittleness After Cold Work

Another illustration, a very striking difference in sensitivity to cold work of steels practically identical in their chemical composition, is shown in the diagram above where tests on two structural grade heats A-2 and A-4, and two medium carbon heats B-2 and B-4 are plotted.

Tests for work brittleness also reveal a considerable spread in the sensitivity of medium and high carbon steels. However, with an increase in carbon content, the impact toughness of such material in the unstrained condition is greatly lowered. For instance, the diagram opposite shows tests on three high carbon steels, of chemical composition given in the table on page 670. The inserts show the McQuaid-Ehn grain size of these steels at a magnification of 100 diameters. The chemical analysis apparently does not explain the difference in sensitivity of these steels. Grain size does not fully explain it either. While the fine-grained steel shows the lowest sensitivity, the two coarse-grained steels exhibit a considerable difference in sensitivity which is not obvious from grain size comparison. These curves may be considered as typical for hundreds of steels which were subjected to this test. As a rule fine-grained steels are insensitive, but coarse-grained steels often exhibit wide differences in their degree of sensitivity.

From the data submitted, it is evident that a test for work brittleness has a selective quality not possessed by either static tests, chemical analysis of common elements, or grain size classification. It separates steels into two major groups—"sensitive" and "insensitive," with perhaps a third "intermediate" group. It will now be shown that the differences between these types of steel are very tangible, and are strikingly reflected in their aging characteristics.

Aging Measured by Work Brittleness

The general aspects of aging have been discussed in recent technical writings by Merica (METAL PROGRESS, 1935) and Sauveur and Harrington (*Transactions*, 1933). The term "aging" broadly covers any change in physical properties of the material taking place in the course of time, and the phenomenon of aging is evidently a more or less gradual transition from a state of metastable to stable equilibrium. Aging takes place either at room temperature, in which case it is termed "natural" aging, or at some higher temperature, in which case it is defined as "artificial" or "accelerated" aging. Its manifestations can be accentuated either by quenching the material from a sufficiently high temperature, or by cold working it.

The "precipitation" or "dispersion" theory offers the most generally accepted explanation of the phenomena. The apparent simplicity of this theory should not exclude from consideration the thought that aging may not be as simple as the theory which attempts to explain it. Merica apparently admits such a possibility when he states that aging "may also occur in consequence of some structural alteration other than precipitation of excess solute."

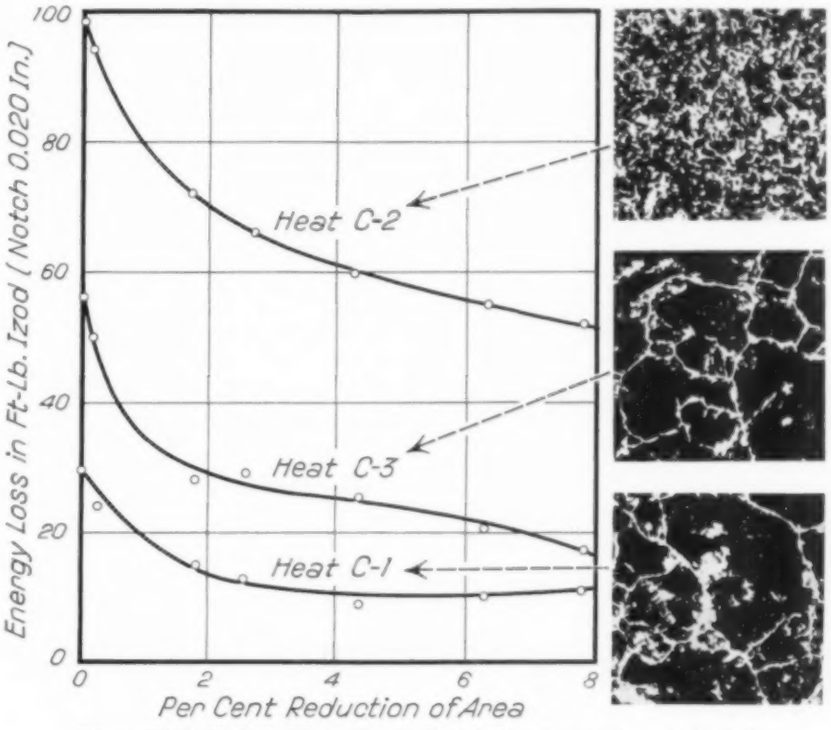
Quench aging, as well as strain aging, generally manifests itself in perceptible changes in both static and dynamic properties. Hardness, tensile strength, and yield point generally increase, while ductility and resistance to impact decrease. Werner Koster's measurements of magnetic changes taking place during natural and artificial aging of steel apparently indicate that both types of aging are similar in many respects, and differ only in the *rate* of reaction (*Archiv für das Eisenhüttenwesen*, 1930), aging at a temperature of 500° F. (260° C.) for a half-hour being equivalent, for instance, to aging at

room temperature for a period of months, or even years.

In view of the great acceleration of aging at above room temperature, such tests may be conveniently used for the study of the total aging capacity of steel, while measurements at room temperature determine the *rate* of aging. From the point of view of the steel user, a knowledge of this rate is more important than that of its aging capacity. Assuming one steel will be completely aged in two weeks, while the other will not reach the same state for a number of years, it is evident that their useful service life and response to fabricating conditions will not be the same, because these differences in their aging rates are reflected in basic differences in some of the other physical properties.

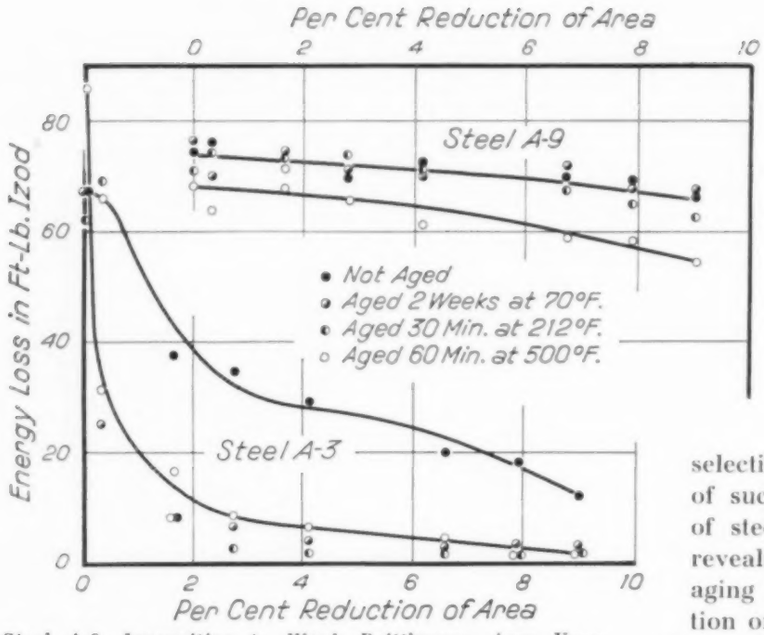
The most common method used in the study of aging phenomena consists in the measurement of hardness changes taking place in the course of time at room temperature or higher. This method is used so generally that the term "aging" is accepted as almost synonymous with "age hardening." In more special cases, changes in other properties are measured. Koster uses magnetic tests, Hayes, Griffis and Kenyon use the tensile tests to evaluate aging effects. In the author's opinion, either hardness or tensile tests fall short of the ideal for the study of aging phenomena because both are static tests and such tests are not sufficiently descriminative. Due to the very pronounced effect of cold work on impact toughness, a work-brittleness test might be logically expected to give a better insight into the behavior of steel under dynamic service conditions.

Experimental data support this conclusion. Curves for work brittleness obtained on steels, *(a)* immediately after cold work, and *(b)* after aging for various time intervals, show a continuous change in the shape of curve until stability is attained. Immediately after cold working, the impact toughness is high, often higher than in the unstressed condition so that the curve instead of sloping downward is often horizontal or else has an upward direction, the impact toughness progressively increasing with each succeeding notch. If the specimen is tested a few minutes after cold working, the curve for most carbon steels starts to assume a downward slope, but the rate at which this change in slope takes place is an individual characteristic of a given heat. The rate is very rapid for some steels and yet it is almost imperceptible on others of similar composition.



Three High Carbon Heats, Equivalent in Analysis, Have Quite Different Work Brittleness. Fine-grained heats are usually insensitive, but coarse-grained heats are often widely different in sensitivity

This difference in behavior is shown in the diagram on the next page, where work brittleness of two structural steels A-3 and A-9 is plotted 10 min. after cold drawing, and two weeks later, as well as after accelerated aging. Steel A-3 is apparently one that rapidly ages. The test taken 10 min. after cold drawing shows a distinct downward slope in the curve for work brittleness, indicating the possibility that considerable aging has already taken place. After aging for two weeks at room temperature, the slope of the curve increases; after aging in boiling water, aging at 500° F. does not introduce further effects. Steel A-9 shows an almost horizontal curve 10 min. after cold work; aging at room temperature for two weeks, as well as aging in boiling water and at 500° F., does not



Steel A-9, Insensitive to Work Brittleness, Ages Very Slightly; Steel A-3 of Similar Chemistry and Tensile Properties, Is Sensitive to Work Brittleness and Ages Sharply

materially change the position or trend of this curve, so that the total aging effects are very slight.

The aging behavior of these two steels is unpredictable from the static tests shown in the table on page 670, and the chemical analyses. They, in fact, represent extreme cases of variation in aging capacity.

In comparison with static hardness and tensile methods of testing aging sensitivity, work brittleness is, therefore, a more selective and illuminating test. A family of such curves obtained on the same lot of steel under different aging conditions reveals not only the magnitude of strain aging effects, but also furnishes information on the degree of cold work at which these effects are most intense. Such information is of obvious practical importance.

Good and Bad Actions of

ALUMINUM IN STEEL CASTINGS

ACTIVELY discussed was the control of porosity in steel castings with aluminum at the Fall Technical Conference held by American Foundrymen's Association in Columbus, Ohio, early in October. C. E. Sims of Battelle Memorial Institute, the discussion leader, cited his recent studies showing the loss of ductility in aluminum treated castings (as measured by unduly low elongation and reduction of area in the tensile test and low impact resistance). These losses are nearly all recovered if a more generous amount of aluminum were used for deoxidizer.

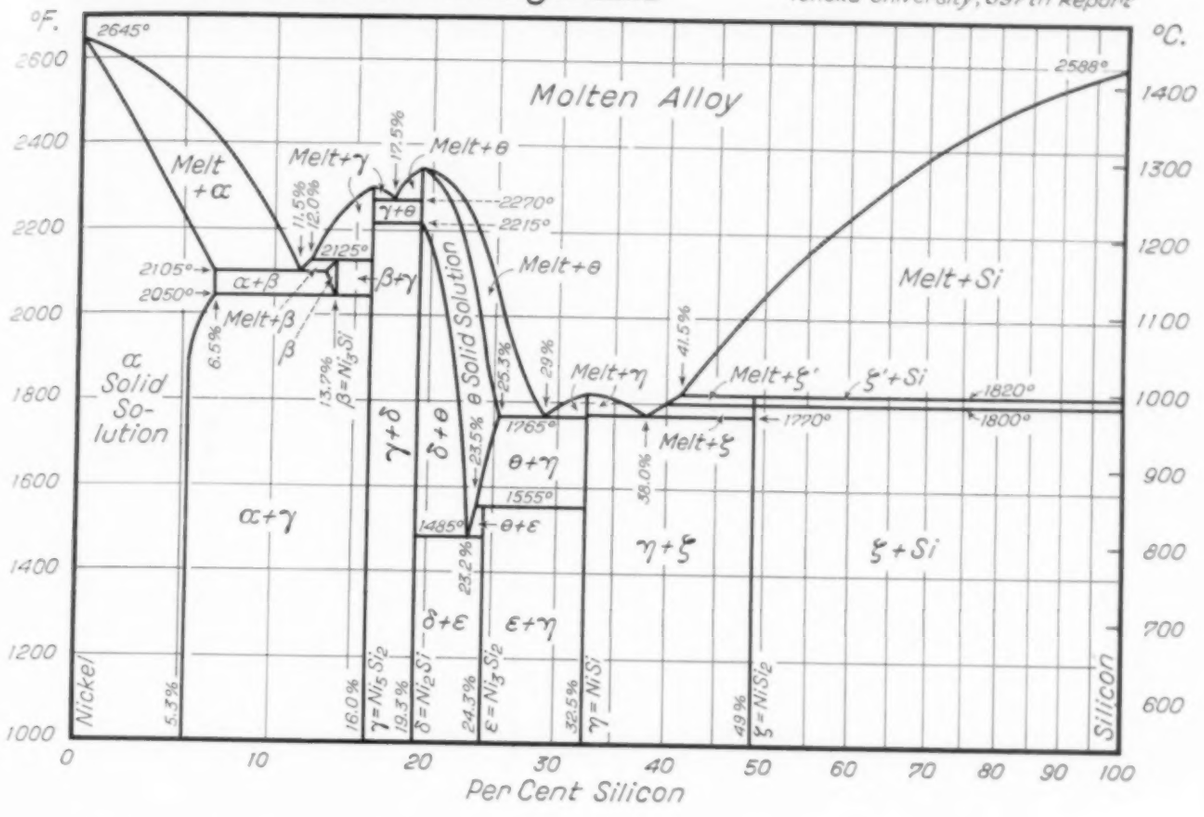
Deficient ductility is apparently due to the influence of aluminum on the sulphides rather than on the oxides. Several melts containing sulphur from 0.02% up to 0.06% were treated with varying amounts of aluminum. The ones containing 0.02% sulphur retained good ductility with all amounts of aluminum, but unfortunately there is no raw material available for their commercial production. For all ordinary sulphur contents the addition of ½ lb. aluminum per ton, while it might correct porosity, caused a drop of nearly half the elongation, reduction of area and Izod impact; 1 lb. aluminum per ton bettered the situation considerably and 1½ lb. brought the physical properties nearly back to the original value. A similar trend of circumstances was observed with modicums of other deoxidizers, specifically zirconium or titanium. In the case of aluminum, careful analysis indicated that only when the higher amounts were added to the molten metal could any residual or unoxidized aluminum be detected in the alloy; lesser amounts were apparently all consumed in chemical reaction with oxides in the melt.

Microscopic observations supported the above statements. A steel casting, deoxidized as usual with ferrosilicon, will contain a con-

(Continued on page 712)

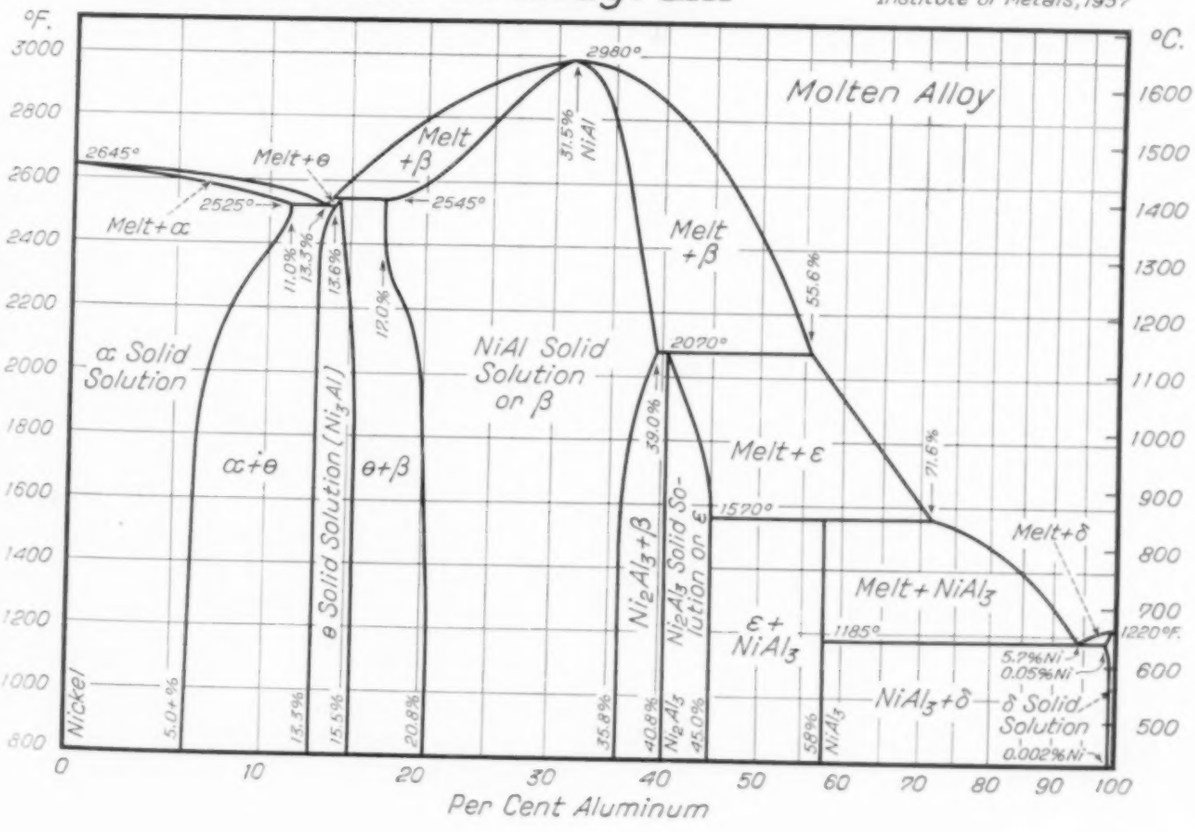
Nickel-Silicon Diagram

Iwaze & Okamoto ; Science Reports Tôhoku University, 397th Report



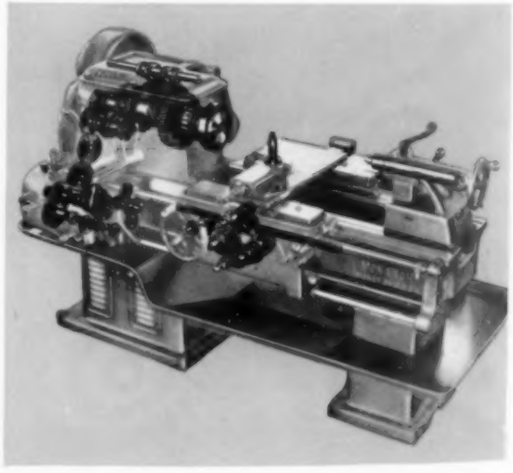
Nickel-Aluminum Diagram

Alexander & Vaughan ; Journal, Institute of Metals, 1937



● The streamlined flier pictured above is the "Super-Chief," Atchison's new light-weight train which makes the run between Chicago and Los Angeles (2,228 miles) in 39 hours, 45 minutes. Such fast time is made possible, because this train of eight cars weighs only half as much as the steam train which it replaces. And responsible for this appreciable weight-reduction is the use of a modern alloy of Nickel, stainless steel. The principle of light-weight construction employed by the Edward G. Budd Manufacturing Co. calls for the use of stainless chromium nickel steel which is fabricated by the Budd "shotweld" process. When you consider the saving in fuel costs and the saving in costs of maintaining road bed and rails, it's easy to understand the constantly growing popularity of stainless steel construction. Perhaps there's equipment in your line of business where the high strength-weight ratio of the Nickel Alloy Steels may be used to bring about worthwhile economies.

● At the left we have another striking example of the cost-reducing advantages of another Nickel Alloy Steel composition. This huge crusher shaft of 3½% Nickel Steel with about .30% carbon, was made by Bethlehem Steel for the General Crusher Stone Co., Easton, Pa. Installed in 1906 it was still going strong in 1930. It was retired from service then, but only because the crusher was obsolete. When equipment parts stand such gruelling service for 24 years, they've certainly paid for themselves over and over again. But that's characteristic of the Nickel Alloy Steels.



● If you have a grumbling gear in your plant it's fairly safe to wager it isn't made of Nickel Alloy Steel. The dark detail in the phantom cut pictured here shows a typical installation of gears and other parts made of Nickel Alloy Steels. The lathe is a product of The Monarch Machine Tool Company, of Sidney, Ohio. Nickel Alloy Steels by Crucible Steel Company of America. Maintenance costs are kept low with Nickel steel gears because they have such high resistance to wear, shock and fatigue.

If frequent gear failures is one of your problems, or if you want to be sure your production cycle has no vulnerable points, Nickel Alloy Steel gears are the ones to specify.

THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N. Y.

CORRESPONDENCE

from home and abroad

Predicting a Fatigue Failure

Are X-Rays Competent?

PITTSBURGH, PA.

To the Editor of METAL PROGRESS:

A reliable means of forestalling breakage of machines and structures from fatigue under repeated stresses would be of immense importance to engineers and metallurgists. For many years there has been a search for some nondestructive test that would reveal the extent of damage caused by repeated stresses and thus predict whether or not the stresses will lead to fracture. Since X-ray methods have been most effective in revealing the internal structure of metals, it is natural that they have been investigated rather hopefully for this purpose, and numerous tests have been reported, both here and abroad, but it is clear from these investigations, it seems to me, that they must be regarded at present as unreliable for practical use. However, papers continue to appear with a favorable attitude toward the X-ray methods which is unjustified by the experimental data.

The publications of H. J. Gough, summarized in the July 1936 and September 1937 issues of METAL PROGRESS, for example, imply that progressive damage can be identified by X-ray diffraction patterns. Gough concludes that patterns that remain unchanged during stressing, or change only at the first application of the load and do not alter their character after this, are characteristic of stresses within the safe range, whereas progressive changes in the patterns indicate unsafe stresses and eventual fracture. A few experiments lately reported by German investigators (see Erich Martin, *Archiv für das Eisenhüttenwesen*, Vol. 10, 1937, page 415; F. Wever and H. Möller, *Die Naturwissenschaften*, Vol. 25, 1937, page 449) state even more conclusively that an impending fatigue failure can be foreseen from changes in diffraction patterns.

The writer had arrived at quite a different conclusion as a result of tests conducted with the cooperation of the Fatigue Committee of the American Society for Testing Materials (see C. S. Barrett, ⓐ Preprint, October 1936; *Metals and Alloys*, January 1937), and this conclusion has not been altered by the experiments published abroad. The important point is that changes in X-ray diffraction patterns reveal cold work from fatigue, not damage. Cold work may occur in the safe range of stress as well as in the unsafe, and may, in fact, be beneficial; so a test that reveals cold work obviously does not afford a direct diagnosis of ultimate failure from fatigue.

Gough's criterion for detecting unsafe stressing (X-ray patterns that continue to change as stressing continues) cannot be accepted as the general case, nor, at present, as a reliable test in any particular case. Too many experiments of different types point otherwise and indicate that cold work in the safe range may continue for millions of cycles. J. B. Kommers, for example, has reported in *Proceedings* of A.S.T.M., 1930-II, page 368, cases where cold work at stresses below the endurance limit must have continued for 15 million cycles or

more, since there was an increase in the endurance limit throughout this period. A number of investigators have also studied the temperature of fatigue specimens during stressing and have found evidence for plastic flow; this is very marked at the beginning of the stressing, but continues in lesser degree for many thousands of cycles. X-ray experiments of Wever and Möller indicate that flow may occur irregularly, with a sudden local deformation appearing after some millions of cycles of stressing during which flow is negligible.

The amount of change in the X-ray pattern also fails to serve as a general criterion for differentiating safe from unsafe stressing. For some metals and for some types of stressing there is very little alteration of the pattern by stressing below the endurance limit, even with the most prolonged tests. But other cases show drastic changes (for example, my own experiments on aluminum); and to make generalization still more impossible, I have reported a low carbon steel specimen stressed above the fatigue limit that showed little or no change in the pattern prior to fracture; similar cases have been reported in steel by Gough and by Wever and Möller. This situation is only to be expected in view of the fact that patterns reveal cold work, for it is generally accepted as the result of various methods of investigation that pronounced cold work sometimes occurs below the endurance limit, while in other cases fatigue fracture may occur with little or no plastic flow. Nor is the amount of plastic flow necessarily uniform over the surface of the metal; those spots where cracks are eventually to occur are doubtless the most highly deformed spots on the surface and probably yield quite different diffraction patterns than neighboring areas where there is less flow. Unfortunately, in most of the practical cases and in many laboratory experiments, the exact place where a crack is about to form cannot be predicted. The experimenter therefore lacks information that is vital in the interpretation of his patterns, for he does not know whether his X-ray beam has happened to fall on a spot of maximum distortion or not.

The experiments of Martin, cited above, by no means justify his conclusion that eventual failure can be predicted, because he tested no samples in the safe range of stresses, ignoring the fact that elastic limit in some materials is lower than the endurance limit. Wever and Möller reported two tests in the safe range of stresses and near the endurance limit; the patterns from one of these tests underwent considerable change after 18 million cycles of stressing, but these authors chose to regard this fact as an exceptional case of no significance, rather than a direct confirmation of my tests and conclusions (at least in this first paper of theirs on the subject).

While I do not wish to discourage further studies of X-rays in fatigue, I think it is important to realize the dangers and limitations accompanying any simple application of the methods—to realize that, in general, there is no assurance that a dangerous state of stressing will be detected, or that what appears dangerous may actually be so. If any circumstances exist in which X-ray tests could be relied upon in practice, they can only be discovered by exhaustive laboratory tests using materials, stress distributions, and number of cycles that will be encountered in practice. At the present time, no conditions have been found for which X-ray tests have been proved a reliable predictor of fatigue failure.

CHARLES S. BARRETT
Metals Research Laboratory
Carnegie Institute of Technology

Fine Dispersion of Lead in Copper

Caused by Lithium

NEW YORK CITY

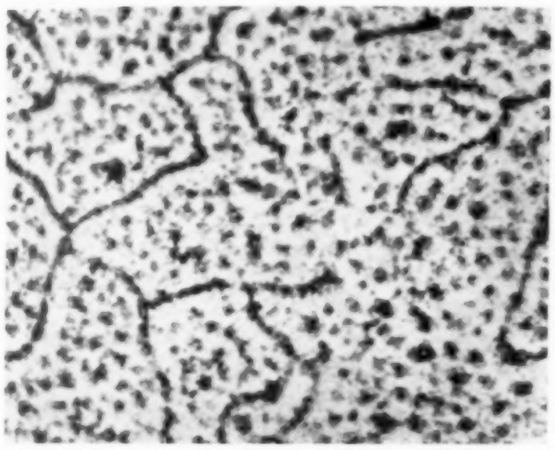
To the Editor of METAL PROGRESS:

We have read with interest the article by Francis G. Jenkins on "Copper-Lead Bearing Metals" appearing in the August issue of METAL PROGRESS, and the comments on this article by J. L. McCloud in September.

The discussion you have invited on bearing metals should prove of the greatest interest to both the manufacturers and the users. Modern high speed internal combustion engines have created a demand for a bearing material having higher physical qualities than the usual white metal alloys. The industry has for several years past devoted considerable attention to this problem of a bearing material that will withstand the increased temperatures and pressures developed in such engines.

It is generally agreed that copper-lead is a most excellent material for heavy duty service as well as for general use. Moreover, there is an abundant domestic supply of both copper and lead and the cost of these metals is considerably less than that of tin, cadmium, nickel, silver and other metals commonly used for bearings.

Heretofore considerable difficulty was encountered in their manufacture. The molten copper-lead was stirred manually or mechanically, and upon casting the metal was chilled or quenched in an effort to prevent the lead from settling out before solidification. The quality of the alloy depended upon a number of variable factors — such as degree of stirring, pouring temperature, mold temperature, time elapsed between cessation of stirring and solidification — which could be brought under control only with the greatest of difficulty, and the



Uniform Fine Dispersion of 40% Lead in Copper When Properly Melted Under an Atmosphere Containing Lithium. Magnification 1500 diameters; etched with aqueous solution of $FeCl_3$ and HCl

results obtained were therefore unsatisfactory and non-uniform.

There has recently been developed a new scheme for the production of copper-lead alloys which overcomes these difficulties. Under this process the metals are melted under an atmosphere produced by introducing into the furnace at a constant rate a lithium compound such as the carbonate. The lithium compound appears to react with the furnace gases so that metallic lithium is absorbed by the molten metal, whereupon an internal automatic stirring of the metals takes place which continues until complete solidification of the alloy. Quick cooling or quenching is therefore unnecessary and the alloy is of uniform quality with an exceedingly fine dispersion of the lead within the copper grains.

Shown herewith is a high power photomicrograph of a specimen (produced under this atmosphere) containing 60% copper and 40% lead with a trace of lithium. A 6x3x1-in. bar of this material on which various 500-kg. Brinell readings were taken near edges and down the axis showed six readings of 28.4 and one of 27.1, thus indicating uniformity of quality. The alloy is oxygen-free and, due to the fine dispersion of the lead within the copper grains, there is no segregation or sweating out of the lead at high temperatures or pressures. Physical qualities are as follows:

Tensile strength	8000 to 10,000 psi.
Elongation	6 to 8%
Ultimate compressive strength	35,000 to 40,000 psi.
Compressive limit	30 to 35%
Brinell hardness (500-kg. load)	25 to 28

This alloy can be readily cast onto a steel back and, due to the cleansing action of the trace of lithium present, a perfect alloy bond is formed between the bearing metal and backing material.

HAROLD J. NESS
President
Nesaloy Products, Inc.

Ductile Zinc Coatings

PALMERTON, PA.

To the Editor of METAL PROGRESS:

I have had occasion to reread Mr. Schueler's article on "Galvanized and Galvannealed Sheets" in the May issue of METAL PROGRESS and Mr. Comstock's very pertinent letter of comment in the August issue. It appears to me that perhaps this subject should not be dropped without some additional comment relating to two very important factors which have not been mentioned by either.

Mr. Comstock refers to the toughness and malleability of the outer zinc layer of a non-peeling, hot-dip zinc coating in which bending produced cracks in the alloy layer but not in the outer zinc layer. It is well known and is, of course, implied in Mr. Comstock's statement that not all zinc coatings are non-peeling. Readers familiar with galvanizing will know, but perhaps it should be pointed out to others, that the ductility of the outer zinc layer is dependent primarily upon its purity and that the use of high grade zinc in wire galvanizing for the production of heavy adherent coatings is based on this fact. Cadmium is the common natural impurity which, in the lower grades of zinc, causes lack of ductility in the outer zinc layer with consequent cracking and peeling. Special high grade zinc and certain brands of high grade zinc are substantially free from this impurity.

The second factor which deserves comment

is the fact that the alloy layer may be of uniform or of very irregular thickness and that the boundary between the alloy layer and the underside of the outer zinc coating may therefore be smooth or may be deeply notched. The effect of such notching on the cracking of galvanized coatings has been well demonstrated. The uniformity of the alloy layer can be controlled to a large extent, since it depends on the smoothness of the steel base at the moment it enters the galvanizing bath. For example, wire that has been protected from rust after drawing and which has required a minimum of pickling to render it chemically clean, alloys with the zinc to produce an even, dense layer of alloy. If the zinc is of proper purity, the result is a coating with good bending properties. A badly rusted wire, on the other hand, will require more drastic pickling and the roughened wire surface will alloy more rapidly and irregularly to produce an alloy layer which deeply notches the zinc coating, and this is reflected in poor bending properties.

W. M. Peirce
Assistant Chief of Research
New Jersey Zinc Co.

Refractory Cast Irons

Turin, Italy

To the Editor of Metal Progress:

From the data available in technical literature, it appears that American and European practice differ somewhat in the field of cast irons resistant to high temperatures.

Refractory cast irons, as they are called in Europe, may be divided in different classes according to their degree of heat resistance.

Ordinary gray cast iron and high manganese, pearlitic cast irons can hardly be considered as metals resistant to high temperature. In general practice, therefore, the simplest class of refractory cast irons is formed by the low chromium irons, containing from 0.7 to 1.0% chromium, and about 1.5% silicon. They generally show a short-time tensile strength of about 50,000 psi. at room temperature, which is reduced to about 33,000 psi. at 1100° F. More largely used in Europe on account of their better machinability are the nickel-chromium irons, containing 0.7 to 1.0% chromium and about 2.0% nickel. A typical analysis of a favorite metal of this class is the following: Carbon 3%, silicon 1%, manganese 0.9%, phosphorus 0.15%, nickel 2%, chromium 1%.

The second class includes cast irons containing between 7.0 and 15% chromium. They keep the structure of a white iron up to the highest temperatures and resist corrosion of hot oxygen excellently. They are largely used in Italy, and somewhat less extensively in France. The typical average composition of this metal is the following: Carbon 3.5%, silicon 2%, manganese 0.5%, phosphorus 0.15%, chromium 8%.

The third class is formed by the ferritic, high chromium irons, containing from 30 to 35% chromium and about 2% carbon. On account of their composition they are generally melted in the electric furnace. They show excellent refractory properties. Their structure — consisting of very stable carbides embedded in a mass of chromium-ferrite — does not change at temperatures even approaching their melting point (this last being considerably higher than the melting point of gray iron). These irons have been studied quite carefully in Germany and Czechoslovakia, and have been rapidly adopted in all European countries. Their tensile strength exceeds 55,000 psi. at room temperature, and remains above 20,000 psi. at 1500° F. in short-time tests. They also show an extremely high resistance to oxidation.

The fourth class includes the well-known nickel-chromium-copper austenitic cast irons. The composition more generally used in Europe for these alloys is about the following: Carbon 2.5%, silicon 2.5%, manganese 2%, phosphorus 0.1%, nickel 15%, chromium 3%, copper 5%. In addition to their excellent refractory properties, these cast irons show a very high resistance to reaction with various chemicals. Their tensile strength is about 42,500 psi., and this changes but little at higher temperatures, even up to 1300° F.

In addition to the alloys included in the above-mentioned four classes, the high silicon and high aluminum cast irons are pretty widely used in Europe, especially on account of their low cost, when high tensile properties are not required. The high silicon irons, containing from 6 to 9% silicon, show good refractory properties, and high resistance to oxidation, but their tensile strength hardly exceeds 20,000 psi. Cast irons containing about 7% aluminum have been used in some particular cases in Europe, but their applications are still limited, notwithstanding their good refractory properties.

Federico Giolitti
Consulting Metallurgical Engineer

The Creusot Centenary

PARIS, FRANCE

To the Editor of METAL PROGRESS:

The year 1936 marked an important anniversary in the history of French metallurgy, as well as of metallurgy generally — namely, the hundredth anniversary of the founding of the Creusot Co., now an organization so well known as to constitute a symbol of the best type of metallurgical enterprise.

On such an occasion it might be opportune to recall some important discoveries made by the staff at Creusot, discoveries whose origin is undoubtedly forgotten or ignored by the present generation.

Metallurgical Apparatus — The steam hammer was invented in 1838 by Bourdon, a Creusot engineer; the first industrial steam hammer, with a weight of about 3 tons and a height of fall of 2 meters, was in operation in the Creusot forge shop in 1848.

The problem of the revolving puddling furnace, unsuccessfully studied by Menelaus, Dowlais and Danks, was solved industrially in 1875 by Bouvard, steel works manager for the Schneider Co. The Bouvard furnace had a water-cooled double wall and a partial partition (likewise water cooled) which permitted the mechanical separation of the charge into two balls which could be easily handled.

Metallurgical Products — Substitution of steel for bronze in the manufacture of gun tubes was the result of methodical and conclusive experiments carried out in 1873 at the Creusot works upon 75, 78.6 and 95-mm. guns. These were completely fabricated in this plant using an extra soft or a medium steel made by the acid Martin process, with tensile strength as cast of 55,000 to 75,000 psi. The President of the Third French Republic, Louis-Adolphe Thiers, wrote a personal letter to congratulate M. Schneider on this achievement.

The Creusot Co. was the first to produce nickel steel industrially to obtain better mechanical properties and higher hardness penetration. Here also tests were made on molybdenum steels, and these steels were produced industrially in the openhearth furnace and were fabricated for various important applications. Molybdenum-chromium steels were also originated at Creusot.

Perhaps the most important contribution of the Creusot Co., however, was the perfection of armor plate. Creusot made the first armor plate of iron in 1854, and in 1876, on the occasion of a competition opened by the Italian Navy, produced the first steel armor plate. Nickel steel armor plate was developed in 1890 and successfully passed the tests made at Annapolis. These improvements were all adopted by other manufacturers.

More recently, Creusot has developed a nickel-chromium-molybdenum steel armor plate which can be hardened to the required depth in thick plates without the time-consuming cementation of the outer surface.

Furthermore Creusot, in addition to its metallurgical departments, has some machine shops containing very powerful equipment. From a historical viewpoint it might be interesting to point out that in 1838 these shops built six 14-ton locomotives for the Saint-Germain Railway; these were the first locomotives manufactured in France for the French Railways.

We shall not discuss here the discoveries made at Creusot concerning heat treatment, such as carburizing with illuminating gas. The laboratories have originated some very important studies of a purely scientific nature. We might quote in chronological order: The study of the tensile properties of materials by J. Barba (1880); the fundamental and classical studies of Osmond and Werth on the cellular structure of steels, which may be considered the origin of all micrographical studies of steels (1885); and Saladin's research on the determination of critical points of plain and alloy steels (1904).

ALBERT PORTEVIN
Editor
La Revue de Métallurgie

Tensile and Endurance Properties

of Cast Al-Si Alloy

CLEVELAND, OHIO

To the Editor of METAL PROGRESS:

I note on page 258 of the September number of METAL PROGRESS, in the article entitled "New Aspects of Fatigue and Creep" by John M. Lessells, errors in the table giving properties of a few important aluminum alloys. The tensile strength of cast alloy S.A.E. 35 with a composition of 5% Si is given as 9000 psi. This should be 19,000 psi. This makes the correct endurance ratio approximately 34% instead of 72% as indicated in the article.

These errors would be quite obvious to anyone familiar with aluminum alloys, particularly because of the high endurance ratio. The

endurance ratio for most aluminum alloys, calculated from data obtained on the basis of 500,000,000 reversals in an R. R. Moore type of fatigue machine, is usually less than 50%. That the errors are not, however, so obvious to those unfamiliar with aluminum alloys is evidenced by their appearance in the article in question. For this reason I believe it desirable that attention be publicly called to the discrepancy.

L. W. KEMPF
Research Laboratories
Aluminum Co. of America

Hardening of Steel

Theory and Practice

SCHWEINFURT, GERMANY

To the Editor of METAL PROGRESS:

In undertaking to prepare a report on the theoretical and practical aspects of hardening, one is confronted with such an abundance of new material and new ideas that it is impossible to present a comprehensive summary in a short space. Hence we are limited to brief sketches of the present status of steel hardening, supplementing those considerations advanced in earlier letters to METAL PROGRESS.

Theory — On the basis of work done by E. Maurer in 1920 in K.W.I.-Eisenforschung in Düsseldorf (Kaiser Wilhelm Institute for Iron Research) a theory was developed to explain the reactions during the quenching of steel, which is recognized today by nearly all metallurgists as "Maurer's hardening theory." According to Maurer, the carbon, in quenching, remains dissolved in alpha iron, that is, atomically dispersed in martensite. An increase in volume is thereby caused which affects the internal stress or interatomic stress — an uttermost type of cold work — and so induces a rapid increase in hardness. A similar interpretation was given by O. Thallner as early as 1898.

With the technical development of instruments capable of measuring and recording the effect of rapid cooling, as well as with the development of magnetic and X-ray methods of testing, it became possible to investigate on a wider scale the phenomena of sudden changes in hardness during the quenching and tempering of steel. F. Wever and his colleagues carried on such investigations at the same Institute. Their experiments confirmed the Maurer hardness theory which, as a result, forms the basis of the present conception of hardening. Wever and Engel's investigations paid particular attention to hardening and tempering, especially the so-called "graded hardening," or "interrupted hardening" — that is, quenching in warm baths.

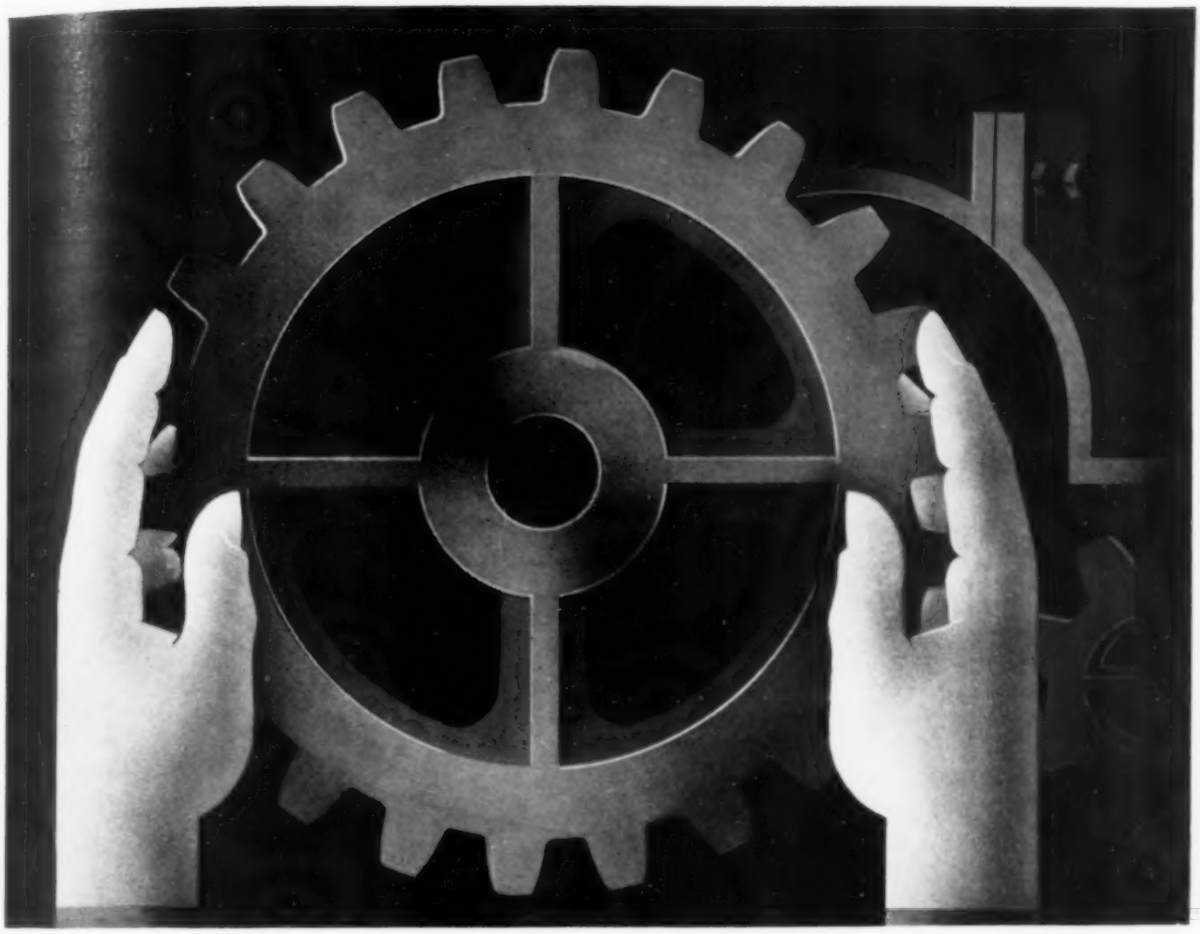
In the space lattice for martensite, as developed by the X-ray investigations of Hanemann and his associates U. Hofmann and H. J. Wiester, it is shown that the η-phase has the same carbon content as the austenite from which it originated. The conclusion is that the carbon is forcibly dissolved in alpha iron, a conception with which E. Maurer agrees.

H. Esser and W. Eilender and their associates at the Technical High School in Aachen, and H. Hanemann and his associates at the Technical College in Berlin carried out further investigations. They support the hypothesis that martensite consists of a highly dispersed heterogeneous mixture of cementite and distorted tetragonal alpha iron particles. Accordingly, the high hardness of the quenched steel can be explained by the blocking of the slip planes in the distorted alpha iron by the precipitated cementite particles. Lattice stresses and cold work, on the other hand, are considered to be less determining factors.

The voluminous researches on the quenching process produced many diagrams and curves; data from only one of which can be reproduced here, showing the location of the Ar" temperature in relation to the carbon content. In this tabulation the results of Wever and Engel, Hanemann and Wiester, and Esser, Eilender and Spenlé agree very well for the temperatures at which, with minimum critical quenching speed, the undercooled austenite will decompose to martensite.

CARBON CONTENT	TEMPERATURE OF Ar"	
0.0%	650° C.	1200° F.
0.1%	470° C.	880° F.
0.2%	400° C.	750° F.
0.4%	325° C.	620° F.
0.6%	280° C.	535° F.
1.0%	190° C.	375° F.
1.4%	130° C.	265° F.
1.8%	70° C.	160° F.

Investigations by E. Scheil in the research laboratory of the United Steel Works in Dortmund and in the K.W.I.-Metallforschung in Stuttgart led to the theory that the transformation of austenite to martensite is evoked by stresses which are caused by quenching as well as by the differences in volume when hot between martensite and austenite. The increase in volume in the transformation provokes further heat stresses. *(Continued on page 688)*



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A Manganese-Moly steel was used—and the problem was solved! . . . Without increase of size or weight, the needed strength was obtained.

Doing the unusual—saving material; increasing weight, strength ratio; simplifying fabricating processes; speeding production and reducing its costs—all have become a regular thing in the fast-moving history of industry's most versatile alloying element. Steels and irons containing Moly are demonstrating their many advantages both in the making and in the performance of many important products and equipment parts.

Our free technical book, "Molybdenum," will prove useful to engineers and production heads interested in cost cutting and product improvement. Our monthly news-sheet, "The Moly Matrix," keeps readers informed on Moly developments. Consult our laboratory when ferrous problems get tough. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

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Climax Mo-lyb-den-um Company

MOLY

PERSONALS

Made chief engineer and factory manager of tube cleaning department, Elliott Co., Springfield, Ohio, plant: **Paul T. Keebler**, formerly tube cleaner engineer at Jeanette plant.

Transferred from Los Angeles plant to Oakland plant of General Metals Corp.: **H. M. Nystrom**, sales department.

Transferred from Massena, N. Y., plant of Aluminum Co. of America to New Kensington, Pa., plant: **Thomas F. McCormick**, metallurgist in extrusion department.

Albert E. Winslow is research engineer in charge of the development and design of rayon machinery for Atwood Machine Co., Stonington, Conn.

Gerald U. Greene has accepted the professorship in metallurgy at Fenn College.

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• stability
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Warehouses in Principal Industrial Centers

Studying toolsteel manufacture at Sanderson Works, Crucible Steel Co. of America, Syracuse, preparatory to sales work: **E. Roy Wildeman**, formerly in the mill control department of the Atha plant.

R. O. Griffis, formerly of Detroit, has been made chief metallurgist of the new hot and cold strip mill plant being erected by Richard Thomas & Co., Ltd., London.

P. R. Wray has been transferred to Pittsburgh to be with Carnegie-Illinois Steel Corp., alloy division.

Herbert W. Whitney, formerly metallurgist at McCormick Works of International Harvester Co., is now metallurgist for Bliss & Laughlin, Harvey, Ill.

Promoted by Lamson & Sessions Co.: **George S. Case, Jr.**, made vice-president and general manager of the subsidiary bolt company in Birmingham, Ala.; **William M. Olsen**, made vice-president and general manager of the Chicago subsidiary; **G. Rider Neff**, made manager of the stove bolt and machine screw sales department; **Alexander M. Smith**, made assistant general manager of the Chicago subsidiary.

Gustav Laub has been appointed assistant vice-president and general manager of sales for Vanadium Corp. of America.

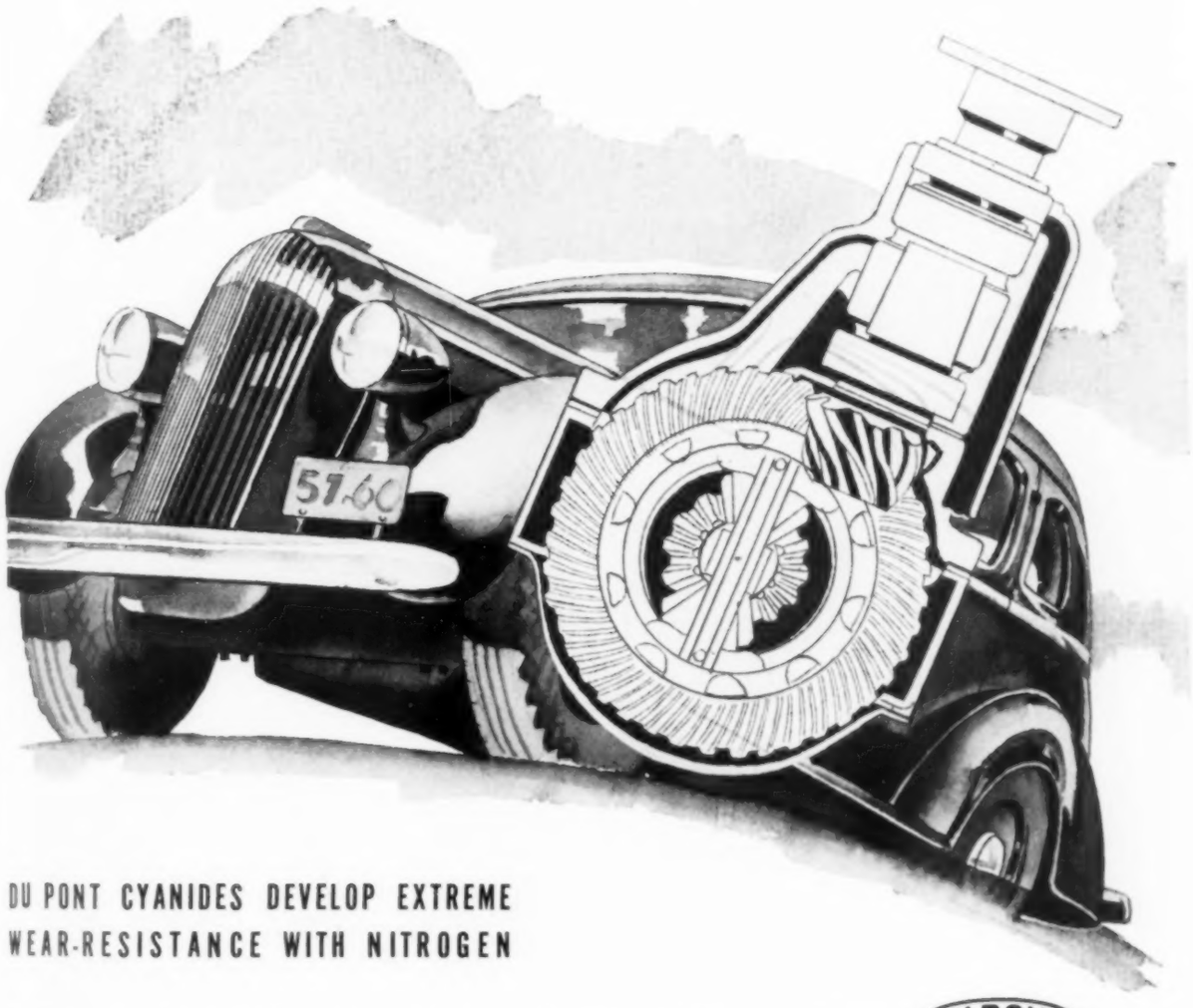
Superintendent of the new extrusion works being built by Aluminum Co. of America at Lafayette, Ind.: **H. B. Kahle**, now head of the Arnold, Pa., extrusion department.

Dwight C. Mayne has been transferred to the Columbus office of Brown Instruments Division of Minneapolis-Honeywell Regulator Co. as sales engineer.

William H. C. Webster is now an observer in the Department of Metallurgy, Carnegie-Illinois Steel Corp., Ohio Works, Youngstown.

D. C. Dilley has taken a position as assistant to Adolph I. Buehler, Chicago.

For **HYPOID** *tooth pressure . . .*



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At present the customary practice in treating a hypoid gear is to pack carburize it to obtain a deep case. The carburized parts are allowed to cool slowly in the boxes. Then, they're removed and reheated in a Du Pont Cyanide bath.

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Du Pont Cyanides are reliable. Their guaranteed content permits molten bath preparations of known strength. Proper control of the time of immersion and temperature, impossible with other methods, gives the exact treatment desired.

Our Technical Service Staff will gladly cooperate with you in the selection and use of the proper Du Pont Cyanides to meet your particular shop conditions.

DU PONT

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Sodium Cyanide, Minimum Strength, 96%

Cyanide Chloride Mixture 75% Sodium Cyanide

Cyanide Chloride Mixture 45% Sodium Cyanide

Du Pont Case Hardener 30% Sodium Cyanide

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PERSONALS

Ralph L. Wilson, trustee and formerly metallurgical engineer of Timken Steel & Tube Division of Timken Roller Bearing Co., is now with Climax Molybdenum Co. as metallurgical engineer in the development field, making his headquarters at Canton, Ohio.

Appointed professor of metallurgy at Massachusetts Institute of Technology: **John Chipman**, formerly associate director of research for American Rolling Mill Co.

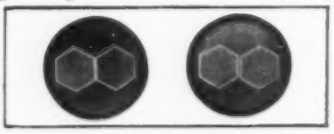
Gerhard Ansel, previously connected with the Metals Research Laboratory of Carnegie Institute of Technology, Pittsburgh, has joined the metallurgical staff of the Dow Chemical Co., Midland, Mich.

9 Lives for Chapmanizing *to* 1 *for* Carburizing

IN ONLY 1 to 4 hours, Chapmanizing imparts a ductile-tough case to free-machining steel that outwears a carburized case 9 to 1. . .and holds its own with costly nitrided alloys.

The process is simple. . .nitrogen is added to iron-base alloys by heating the metals in the presence of nitrogenous material. Bath retains long-term stability. Parts come out silver-clean, free from soft spots. They can be bent, straightened or abraded without cracking or warping. And they require less time for machining and finish-grinding.

Chapmanizing involves no special furnace. . .no investment. Simply install the Chapmanizer Unit on a contract basis, hook it up to your present furnaces. Find out whether this patented process can cut your costs and improve your product as it is doing for others. Write for new book.



Case Depth, 1 hour of Chapmanizing on SAE 1315 steel.

Case Depth, 4 hours of Chapmanizing on SAE 1315 steel.

The **CHAPMAN VALVE**
MANUFACTURING COMPANY
INDIAN ORCHARD. MASSACHUSETTS U. S. A.

R. C. Solomon, Jr. has terminated employment with the Granite City Steel Co. and is now in the metallurgical department of the Tennessee Coal, Iron and Railroad Co., Ensley, Ala.

With Briggs & Stratton Corp., Milwaukee: **Walter E. Steffens**, formerly with the Murphy Diesel Co., Milwaukee.

Promoted by American Steel & Wire Co.: **J. R. Thompson**, to assistant manager of the metallurgical department at Cleveland; **L. H. Dunham**, to district metallurgist, Chicago district; **R. H. Barnes**, to district metallurgist, Cleveland district; and **R. R. Leo**, to assistant division metallurgist at Cleveland.

E. R. Torgler has been promoted from metallurgist to factory superintendent of S. R. Dresser Co.

R. R. LaPelle has joined the staff of the Gas Machinery Co. as a furnace engineer.

John Howe Hall has resigned as technical assistant to the president, Taylor-Wharton Iron & Steel Co., to engage in consulting practice as metallurgical engineer.

John S. Roney of Cleveland has become manager of industrial sales for Park Chemical Co., Detroit.

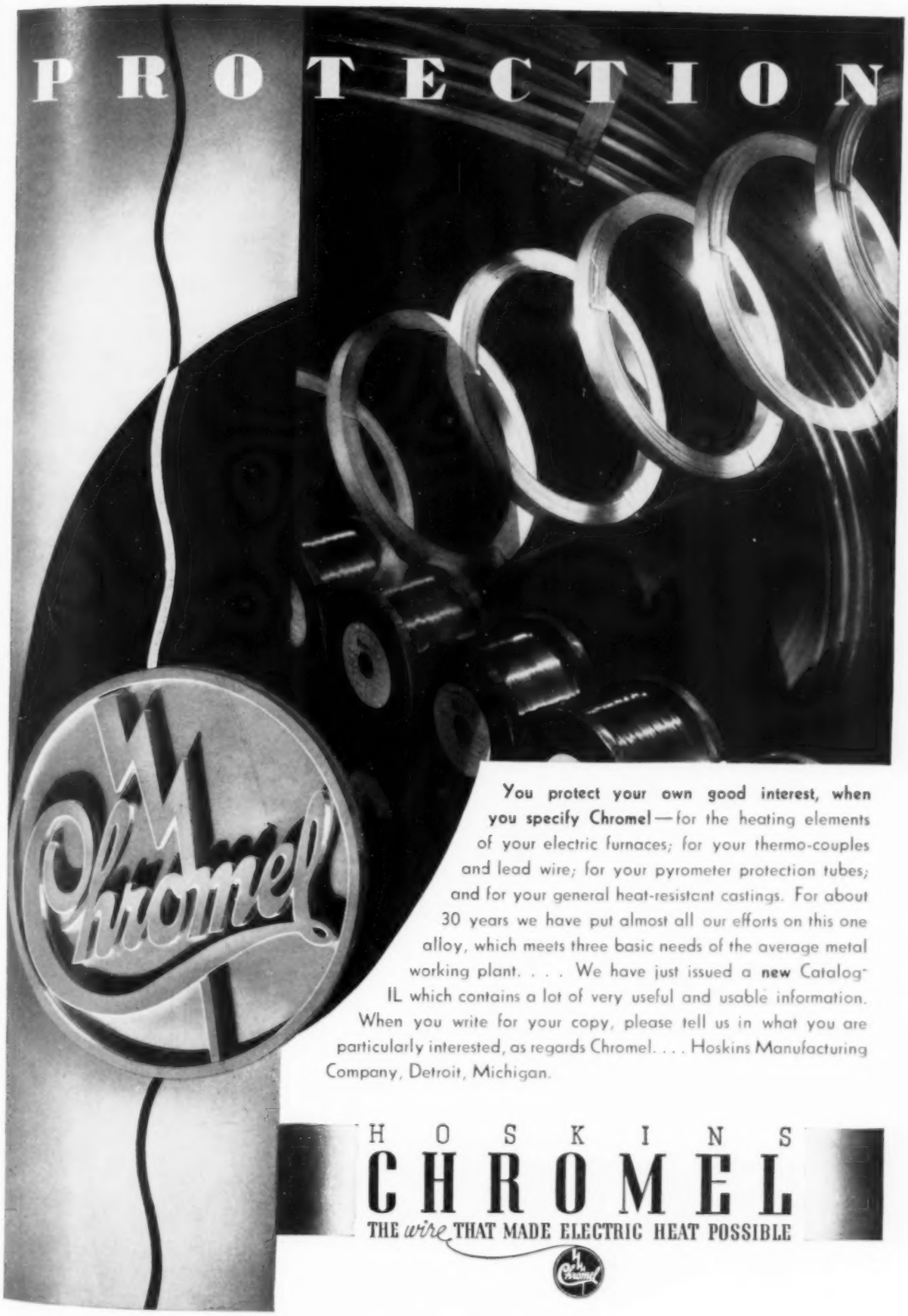
Now with the Marietta Mfg. Corp., Indianapolis: **M. N. Gould**, formerly with Ball Bros. Co., Muncie, Ind.

Assigned to the Cincinnati office of Timken Steel & Tube Division of Timken Roller Bearing Co.: **Robert R. Elsasser**, salesman.

Thomas E. Cooper is now doing sales work for Air Reduction Sales Co. in Cincinnati.

Promoted by Rheem Mfg. Co.: **R. D. Patterson**, from maintenance engineer at South Gate to production manager at Houston.

Wilson Lynes, formerly metallurgist for Henry Disston & Sons, Inc., is now in the research and development department of Revere Copper & Brass, Inc., Rome, N. Y.



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CHROMEL
THE *wire* THAT MADE ELECTRIC HEAT POSSIBLE

STEEL HARDENING

(Continued from page 682)

Scheil's work reached a definite conclusion in 1935 and 1936 when he was able to *hear* the martensite transformation through a microphone and loud-speaker. The sudden change in structure caused by the transformation gave weaker and louder sounds in more or less rapid succession.

A summary of German thought may be found in two books, one by E. Houdremont, "Einführung in die Sonderstahlkunde," and one by P. Oberhoffer, "Das technische Eisen," Third Edition by W. Eilender and H. Esser (already reviewed in METAL PROGRESS). These books discuss a great many investigations, and fairly complete information on the present status of thought in Germany may be found in them. An exhaustive discussion of the latest information on hardening and tempering of steels is likewise found in Gmelins' "Handbuch der anorganischen Chemie," Section No. 59 on Iron.

Hardening Methods in Practice — Hardening methods may be classified for two large groups of steels as follows: Direct hardening steels and casehardening steels. Contrary to American practice, the direct hardening steels are used in Europe for many purposes, particularly because parts of high strength and simple practical requirements can be manufactured from them more cheaply.

Nevertheless, substantial improvements in casehardening methods are responsible for very extensive use of this process. Powdered carbon of all types, salt baths, and gases are used for cementation. Most processes provide for the diffusion of carbon to form the hardened surface, but nitrogen is also used to a lesser extent.

Nitrogen hardening, which was developed by the Krupp company — and also double nitriding for special parts — has received a great deal of attention. These matters were discussed in a special issue of *Technischen Mitteilungen Krupp* for July 1933.

Graded hardening, which came into use in Germany as the result of work by Wever and Engel, has already been discussed in my letter to METAL PROGRESS (March 1933).

Next to hardening, tempering is also accorded particular attention, since it exercises a decisive influence on the soundness of manufactured parts.

The following factors are necessary in parts to be hardened:

1. Attainment of the desired strength and hardness, toughness, elongation, corrosion resistance, and other properties.

2. Minimum distortion in hardening.

3. Minimum distortion of the manufactured part either in storage or in operation by so-called aging — that is, deformation caused by alteration of stresses in the structure.

While formerly hardness was judged in the production line by the fracture test and the file hardness test, the microscope is used in many shops for continuous hardness control, since the degree of refinement now required can only be obtained with the microscope. Furthermore, studies of structure and hardness made on a tempered test specimen give more information concerning actual hardness than direct hardness testing. Considerable improvements have thus been made in recent years. Partly responsible for this development is the fact that the hardening foreman and the metallurgical engineer have worked together in the shop.

Chemical composition of the steel and the annealed structure are carefully watched, since slight changes in alloy constituents are likely to result in an improper structure when hardened. In the production line carbon content under 0.35% is not permissible if a uniform hardness of about Rockwell C-40 to C-50 is to be obtained after hardening and tempering. Steels with 0.30 or 0.32% carbon are very likely to be afflicted with soft spots.

Heat Energy and Furnaces — Depending on economy, geography, requirements for quality, and operating conditions, our furnaces are fired by coal, producer gas, oil, central station gas piped from a distance (see METAL PROGRESS, February 1931), city gas or electricity.

Significant improvements have been made in all types of furnace construction. Special attention, however, has been paid to gas and electric furnaces, and the direct use of coal and of oil has been losing ground. Gas heated furnaces have long been preferred because of the controlled atmosphere they may provide. The new electrically heated furnaces, however, also can operate with a specially manufactured protective atmosphere.

Choice of gas or electricity as a source of energy today, therefore, is made less from a standpoint of quality of the work than from a standpoint of economy. This question as to whether gas or electricity *(Continued on p. 690)*

Furnaces
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We build furnaces for hardening, tempering, annealing, normalizing, forging, stress-relieving, extrusion, coloring, and other industrial applications. Many companies have profited by the operating advantages of our furnaces.

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For testing the Qualitative and Quantitative hardness under the static method of all known materials including dead soft or superhard metals, sub-surface testing, etc., send for bulletins M-3, M-6 and M-7 descriptive of the MONOTRON, now in general use.

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It controls electric heat directly, or oil or gas fired units with motorized or solenoid valves. A red bull's eye indicates whether the heating unit is on or off.

It has no motors, no depressor bars, no contacts to stick or become inoperative. The temperature indicating pointer is free at all times to give continuous indication and hair-line control.

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STEEL HARDENING

(Continued from page 688)

is preferable has been very extensively discussed in the technical literature.

Modern German electric furnaces, for instance, are summarized in *Siemens Zeitschrift*, Berlin, June 1937. In addition to melting furnaces, the article thoroughly covers annealing and hardening furnaces from the simplest muffle furnace to tower furnaces about 50 ft. high for bright annealing and tempering of strip steel in the production line. METAL PROGRESS, April 1932, also contains a few thoughts on certain types of German hardening furnaces.

The subject of gas heating is treated in a special issue of *Technischen Mitteilungen Krupp*, (No. 20, 1935). A second special issue (No. 2, 1936) is similarly devoted to the subject of heating with electricity.

Quenching Machines — Cooling of steel parts for the purpose of hardening was formerly done in simple containers filled with oil, water, or other medium. In consideration of the importance of proper cooling of the part to be hardened, these simple operations have been developed into more and more efficient mechanisms capable of exact work corresponding to the requirements for quality and economy. The quenching medium has been set in motion by means of pumps and propellers in order to obtain the desired uniform cooling. Housing pins, dies and other suitable apparatus are used in order to reduce distortion of the part being hardened to a minimum. Quenching machines are generally made by firms specializing in this line, but are sometimes designed in the plant with a view to individual problems which might exist. Development in this field is not yet finished; the next few years will certainly witness substantial progress.

Tempering Equipment — Methods of tempering, as well as quenching methods, have also received ever-increasing attention both as to theoretical knowledge and practical experience. Corresponding to improved hardening and quenching apparatus, modern equipment for tempering has come into existence in which the use of high and low temperatures and the time of tempering are more significant than the type of tempering medium.

HANS DIERGARTEN
Chief Metallurgist
United Ball Bearing Works (SKF)

Industry's New Horizon Lies Southwestward . . . .

The Southwest—and South Texas in particular—is new country for the industrialist, but not an uncharted industrial wilderness. An already considerable industrial development has proved the Texas coast country as industrial territory; industries-on-the-ground showed the way to pioneer immigrant industries, and these have blazed a trail which others are beginning to follow in increasing numbers.

It will pay you to investigate the diverse natural resources of South Texas for your own company. For the next year—but possibly not longer—new industries on the Texas Coast will still be pioneer industries, with the pioneer's rich opportunities. To assist you in your investigation, we will prepare for you a highly individualized, strictly confidential survey of South Texas, its resources, its markets, its various industrial facilities. The survey will be factual, accurate, specially compiled to furnish you with the exact information your specific company requires. To secure a survey in time to make plans for next year (each takes about 30 days to prepare), send for yours as quickly as possible. There is, of course, neither cost nor obligation.

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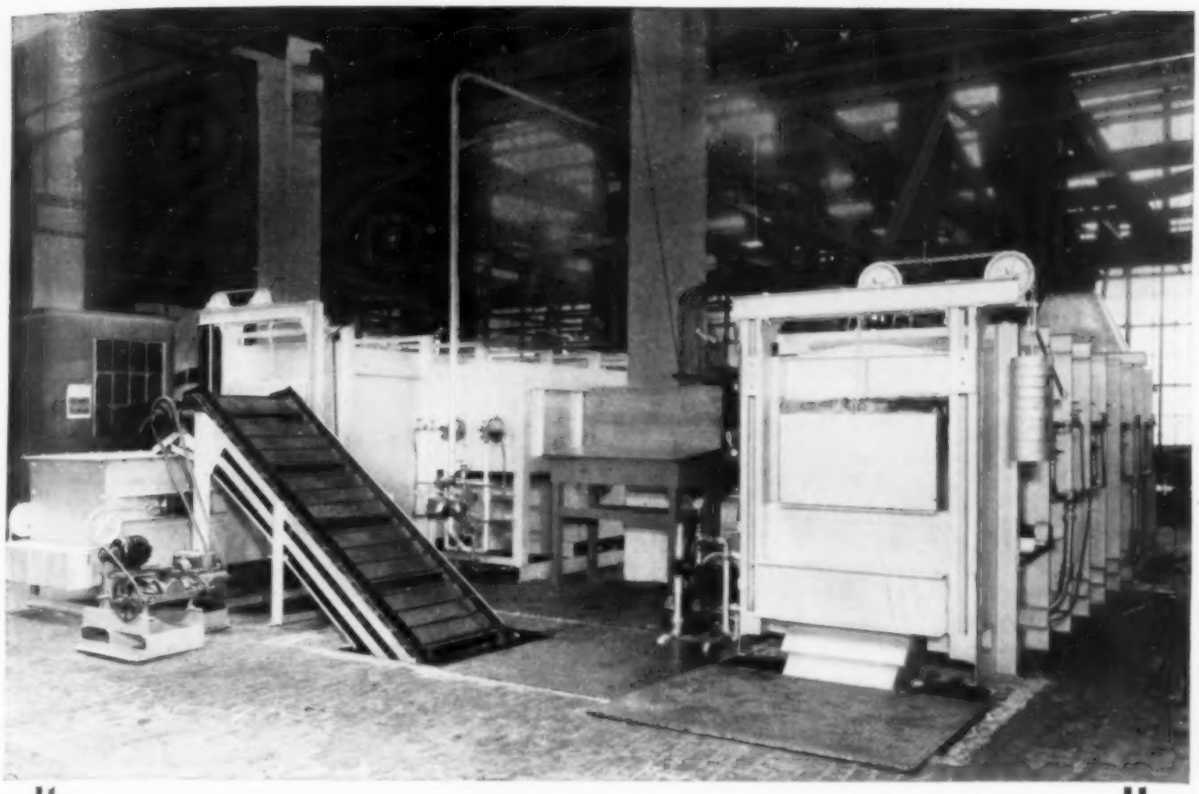

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Consists of Hardening Furnace, Quench Tank for oil or water, and Convection Type Drawing Furnace. All conveyors allow for treating work from ¼" diameter x ½" long to pieces 24" wide x 36" long.

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Specialists for over a quarter of a century in complete line of Steel Treating Products—

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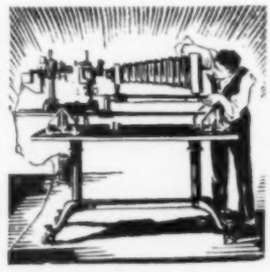
PARK CHEMICAL CO.
DETROIT

CANS FOR FOOD

(Continued from page 660)

undertaken, and the difficulty was found to be due to a particular method of manufacture of the steel base. Other factors such as the thickness of the tin coating and differences in chemical composition of the steel base caused minor but measurable variations in the corrosion rate, but the method of production of the steel base had so marked an effect that other variations were insignificant. This research, though time consuming and costly, paid for itself many times over, as it gave an answer to a question for which the right answer was imperative.

In closing may I suggest a few lines along which it seems as if metallurgical research would be profitable? Why is a *tin* can necessary? Tin is costly and is a strategic material of which we have no domestic supply. Is no other material suitable for the preserving of food? Aluminum alloys are certainly possible but at present too costly. Some grades of stainless steel would be quite satisfactory but again are too costly for this purpose. Would it not be possible to produce at a reasonable cost duplex sheets with the corrosion resistant metal rolled into the steel base? Or again why not use an untinned steel can? Automatic welding methods could surely be developed to make the fabrication simple and solderless. A steel can would be unattractive on the grocer's shelf and would soon rust but could it not be protected by a suitable varnish at a cost less than that of tin? How about an oxide protection of the Parkerizing type? Housewives might object to a black can but could probably be educated.

Are all the metals used in the canning operation itself wholly satisfactory? Cannot cookers, steam kettles, screens, pipe lines and other pieces of equipment be improved? If such questions as these could be answered, a sure basis of future progress would be laid.